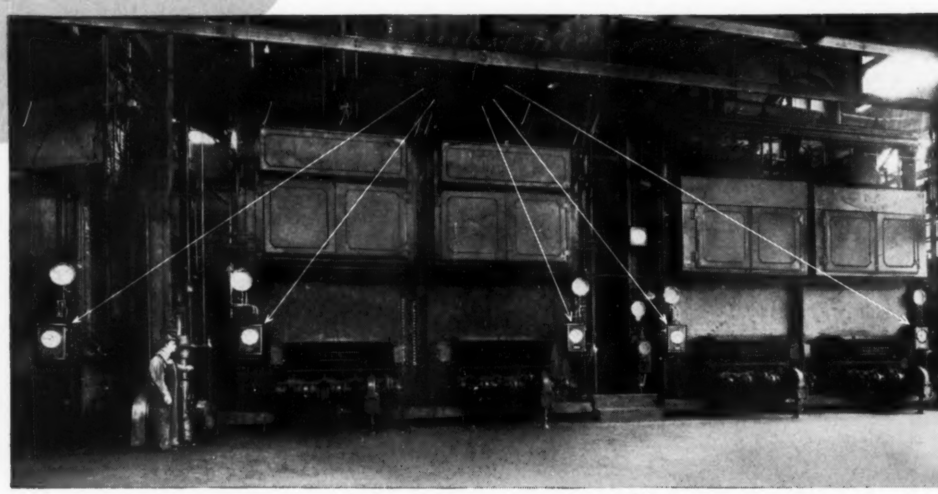
MECHANICAL ENGINEERING

June
1933

GALLOWAY

Another EXAMPLE of Fuel Savings



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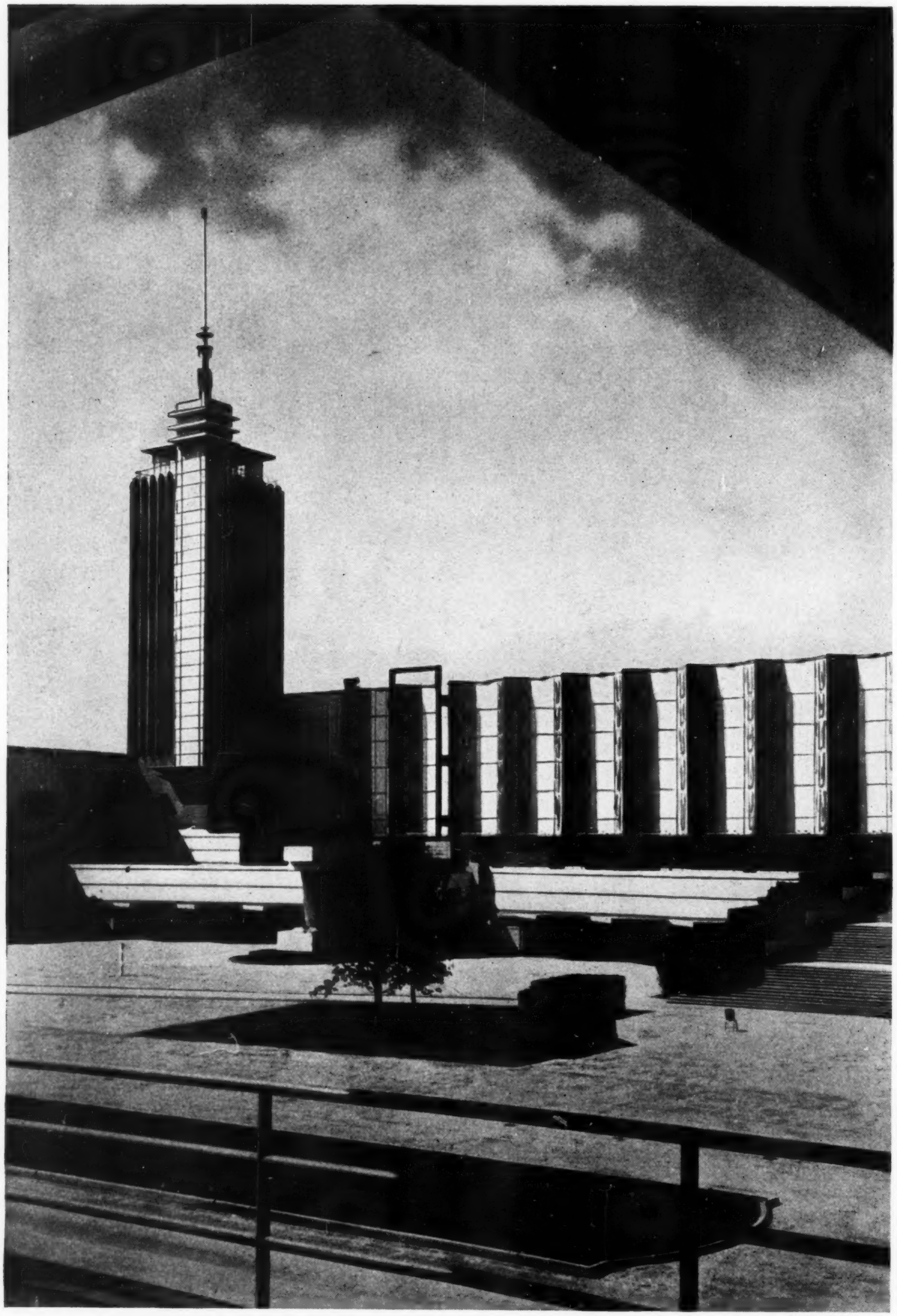

Ewing Galloway

Hall of Science—A Century of Progress Exposition, Chicago

A CENTURY *of* PROGRESS *in* FUEL TECHNOLOGY

A Review of Conditions One Hundred Years Ago

By O. P. HOOD[1]

FUEL technology deals with that orderly arranged group of facts, derived from observation and correct thinking, which have to do with the major combustibles used in the arts. Although the subject is old, the term is of recent origin, coined since we began to depend so largely upon the burning of fuel to produce power.

Man's mastery of fire has proceeded by irregular advances. He probably first used it to protect himself from the rigors of an unfriendly climate, and then to make his food more palatable and healthful. Later, fire gave him better weapons and developed his arts. Of late, it has given him a tireless substitute for human and animal slaves and a degree of power over his environment beyond the imagination of ancient poets.

At some time during the past one hundred years the energy derived from fuel by means of heat engines surpassed for the first time the energy obtained from all other sources. This extensive enslavement of fire is one of the major characteristics of the past century. It is probably the most disturbing factor that ever impinged against a well-established culture. It has provided conditions at once the hope and the despair of the present generation.

The hope that we can provide ample quantities of food, clothing, shelter, and leisure for every human being has, within a generation, been proved to be a reasonable one, to be accomplished through the intelligently directed use of heat-produced power. That we have not learned to distribute these possible blessings to every person is the present despair of statesmen and social thinkers.

THE STATUS OF FUELS IN 1833

If, one hundred years ago, the term "fuel technology" had been used, it would have applied to a relatively simple group of fuels and facts. To show the century's progress in fuel technology it will only be necessary to picture the general fuel situation in the United States in 1833 and compare it with the great fuel-producing and fuel-using industries of today.

The common fuels of that time were wood, anthracite, bituminous coal, and charcoal. The wooded portions of the continent were still being attacked to make smooth fields for farms. In many places wood was still a nuisance to be rid of. In 1828 it was estimated that of the total consumption of fuel, 80 per cent was wood, 3 per cent charcoal, 2 per cent bituminous coal, and 14 per cent anthracite.

An English writer as late as 1840 said:

> The common fuels in the cities and towns of the United States consist chiefly of wood, of which there are various kinds. The best is the celebrated hickory tree, which commonly fetches a price equivalent to about twelve shillings per load; it is a desirable fuel and does not soon die out. Oak billets are next in esteem, and sell for nine shillings; gumwood, dogwood, and pinewood are an inferior description of firing and fetch six or seven shillings the load, according to circumstances.
>
> The quantity to be accounted a load is fixed by law, and the logs, which are about four feet long on the cart, are sawed into short billets, previous to being piled in the cellars of the consumer by the hawker of the fuel, or some person who accompanied him with a saw on his back.

Many of us recognize this picture and took part in the sawing in much more recent times.

In 1833, Walter R. Johnson, professor of natural philosophy and physics, University of Pennsylvania, advised that a house could be heated by a single furnace in the cellar and that the system had been used in some public buildings and to a very limited extent in private dwellings. In urging the adoption of this new method he referred to inefficient fireplaces and disclosed that both New York and Philadelphia expended the enormous sum of 1200 and 1500 thousands of dollars annually for combustibles. He believed that the gradual introduction of mineral fuel, especially anthracite, would probably produce some changes in domestic arrangements. Thus prophecy was amply fulfilled. Some form of centralized heating of houses is now nearly universal.

The cost of wood was largely that of transportation, so that as nearby forests disappeared, the cost of heat began to be a serious item of expense in the larger towns and in some industries. In 1831 there were in the United States 939 small furnaces and forges producing 191,536 tons of pig iron, all using charcoal for fuel. Coal had been tried and was considered a failure.

In 1835 a gold medal was offered by the Franklin Institute to the person in the United States who would manufacture the greatest quantity of iron in one year, using bituminous coal or coke as fuel, "the quantity to be not less than 20 tons." Coke was much used in England and rails for the budding railroads were being

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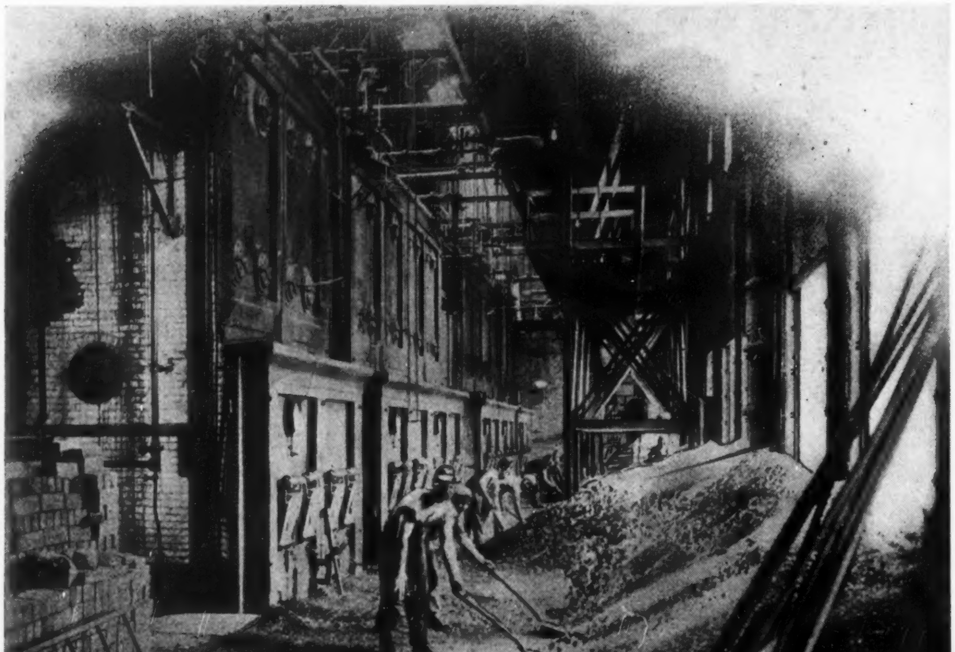
Contributed by the Fuels Division for presentation at the Semi-Annual Meeting, Chicago, Ill., June 25 to July 1, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.



Courtesy Babcock and Wilcox Co.

THE ADVANCE OF FUEL TECHNOLOGY HAS ELIMINATED HAND-FIRING IN LARGE PLANTS

was looked upon as a great curiosity. Upon Austin's suggestion, Captain Barker agreed to give the new fuel a trial under the boilers of the *Marco Bozzaris* and ten "barrow-loads" were placed aboard the boat. The steamer did not work well with it, however, for her boilers were made for the use of wood, and she could not be made to keep up steam with coal—much to the chagrin of Austin, who made the trip on the boat that day to witness the experiment. Thereafter wood was used as long as the steamer remained on the route, and under that fuel she is said to have performed admirably.

A century ago the idea of steam railroads was having its first boom. In 1830 there were about 40 miles in short lines. In 1832 there were completed or in progress 19 railroads with upward of 100 miles completed out of a projected length of 1400 miles. Some of the vertical boilers of the first engines used anthracite, but with the rapid evolution of the locomotive, wood was depended upon for fuel because coal had proved to be hard on the boilers. Coal has always been the scapegoat for poor furnace design and bad combustion habits, and it is suspected that this early ill repute was no exception. Early boilers carried no steam gages and were fired until the safety valve lifted. When this occurred, the firedoor was left open until the valve closed. That tube sheets and tube ends protested by leaking was laid to the bad effects of coal as giving too concentrated a heat instead of to bad practice, and for many years wood was therefore preferred.

The story of coal in the United States has been told many times. It is an interesting fact that the first discovery of coal in the area now covered by the United States was made within 75 miles of Chicago. The French explorer Hennepin, in 1698, found coal near Ottawa on the Illinois River. In 1700 the coal area near Richmond, Virginia, was known, and this was mined as early as 1775. This was the most productive coal field in the United States in the early part of the 19th century, reaching its maximum output of over 142,000 tons a year in 1833. This coal was quite generally distributed in the seaports along the North Atlantic coast.

In the Pittsburgh district a coal mine was worked in 1760, and with the advent of the first steam engine there in 1794, the demand for coal in that district increased rapidly. In 1825 the amount of coal used in this vicinity was 3500 tons per year. It is recorded of some of these early mines in the hillsides above the river that the coal

imported because coke-made iron in England was so much cheaper than charcoal-made iron in America. Our furnaces were situated in the wooded districts of the Appalachian area near supplies of ore and limestone, but the forests were rapidly being depleted and costs were increasing. Some furnaces had shut down for lack of fuel. It was about 1840 before we learned how to make iron with our coals.

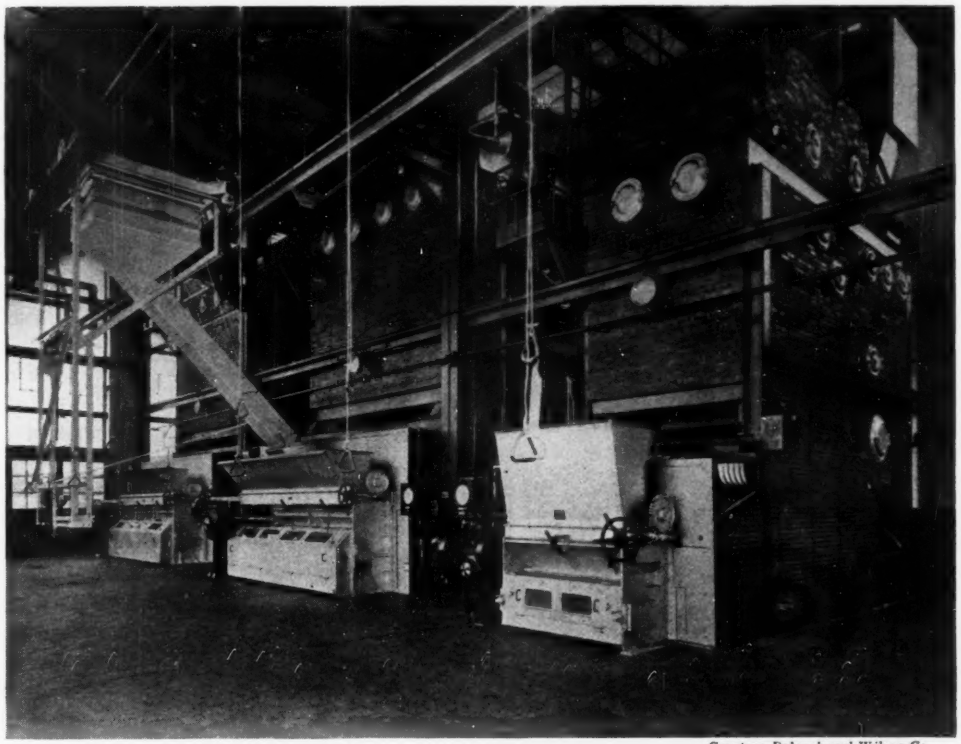
Robert Fulton's first steamboat, the *Clermont*, in 1807 "was fed with dry white pine wood," although the desirability of using coal was realized in the earliest stages of steamboat development. When Nicholas Roosevelt, in 1809, floated down the Ohio and Mississippi rivers to study the feasibility of organizing a steamboat line between Pittsburgh and New Orleans, he made arrangements to open coal mines along the Ohio River to supply coal for his boats. However, when the first steamer of this line was put into commission in 1811, it used wood. In 1833 there were less than 100 steamboats all together, and up to 1836 the principal fuel for them in the United States was wood.

Typical of the time was the experience with the new steamboats running between the island of Nantucket and the mainland. This was an important center for whale oil, used for lighting and lubrication, and the first steamboat of 80 tons began running to New Bedford in 1818. It burned wood. The third boat of 120 tons made a trip across Nantucket Sound using coal for fuel for the first time in June, 1831. Quoting from "The Story of the Island Steamers:"

This coal had been brought to the island in a sloop at the instance of Isaac Austin, and was dumped on the wharf in a small heap, where it

was tied up in raw hides and rolled down the hill to the river bank to be taken by barges to Pittsburgh. The pioneer miners of the Monongehela valley early began the use of dogs to assist them in hauling coal from the working places to the dump at the mouth of the mine.

In 1806 coal of a superior quality for blacksmithing was mined near the headwaters of the Tioga River and by 1833 was being carried by raft down the river to Corning, N. Y., whence it was distributed to the regions to the east and west. In western Maryland coal was discovered in the Georges Creek district in 1804, but it was not until 1830 that the first shipments were made eastward on the Potomac River by means of barges. Coal was mined in a small way in the states of Illinois, Indiana, and western Kentucky for shipment to market, and it was just being advertised for sale in newspapers in Indiana in 1832.



Courtesy Babcock and Wilcox Co.

MECHANICAL DEVICES HAVE NOT ONLY ELIMINATED MUCH BACK-BREAKING TOIL BUT HAVE BROUGHT ABOUT CLEANER BOILER ROOMS

This shows that one hundred years ago bituminous coal mining was being carried on for the benefit of local communities, but the industry was beginning to reach out boldly for more distant markets.

There was discovered near Wilkes Barre, Pa., in 1762, a stone coal so hard to ignite and so slow to burn that it failed to take its proper place in the scheme of things for many years. A wood fire could be started on a bed of ashes and bituminous coal could be ignited and burned in the same way, but anthracite would not kindle or burn in that manner. To poke a wood or a bituminous coal fire was instinctive and soon became a habit, but it was necessary to let anthracite alone.

These simple facts of technique stood in the way of the successful general use of the stone coal. A few blacksmiths could use it as it would burn if provided with a blast, but the general opinion was that it was not good as a domestic fuel. In the early days of the 19th century a number of experiments were made with anthracite on a grate, and it was considered a noteworthy fact that it burned with ordinary chimney draft. Charcoal for industry was getting scarce during the War of 1812 and bituminous coal from Virginia could no longer be had, so that renewed efforts were made to use anthracite in the Pennsylvania district. Progress was slow. Added to skepticism about the coal there were very serious transportation problems, but by 1833 these handicaps were sufficiently removed so that more than 487,000 tons were marketed in that year.

We may say, then, that 100 years ago we were on the threshold of a most remarkable development of this most remarkable coal. About the year 1820 the use of anthracite first exceeded that of bituminous coal, and it was not until 1870 that anthracite lost its lead. During that half century, this supreme fuel put an enduring stamp upon the domestic and industrial habits of the northeastern states. Fear of a shortage of charcoal was laid to rest.

There was no coke industry 100 years ago. As early as 1810 coke had been made in ricks by methods closely resembling those used in making charcoal, the yield being about 55 to 60 per cent. The Pennsylvania Society for the Promotion of Internal Improvements sent an observer to England in 1825 to study developments in coke making. But the first coke ovens in the Connelsville district were not erected until 1841. Although coke was being made and used successfully in England, it was slow in getting started in America.

In 1833 petroleum was known as a medicine and as a nuisance. In the valley of the Little Kanawha there was a spring from which 50 to 100 barrels of petroleum were collected annually. Small quantities were found in springs and streams in the Allegheney River district and in Kentucky. A little was collected and sold as Seneca Oil for 50 cents for an 8-ounce bottle. When it was found in the salt wells of the Ohio valley, it was considered a nuisance.

Natural gas was a curiosity. Fredonia, N. Y., a few

Ewing Galloway

FIRING A BOILER BY HAND CALLS FOR STRENTH AND SKILL

miles from the shore of Lake Erie, had a supply of natural gas that was conveyed through a $^3/_4$-in. lead pipe from a shallow dug well. In 1829 the village adopted a town seal on which was depicted a five-jet gas burner. But natural gas as a fuel in quantity came in more than twenty years later with the petroleum development in the fifties and sixties.

Lighting by manufactured gas was a rapidly growing industry in 1834; London had 168,000 gas lamps and employed 2500 people in the business. In America, the first manufactured-gas company was organized in Baltimore in 1816. Gas lighting began in Boston in 1822 and in New York in 1833. Coal from the Richmond basin was being used for gas making, and the technology of this art was just beginning in this country. It was replacing whale oil and lard oil in public lighting.

Glass works had been abandoned in several localities for lack of charcoal, and the industry was centering largely around Pittsburgh where coal had been used from the beginning of the industry. The use of coal was one of the outstanding features of the first successful glass house erected in the Pittsburgh area in 1797. Other factories before this and long afterward used wood for heating the furnaces. The Kensington plant used each year in the furnaces, in addition to wood and coal, about 15,000 barrels of resin from North Carolina. In 1831 whale oil at 30 cents per gallon was being used for lighting, and the rapid increase in price was stimulating the development of substitutes. The distillation of oil from coal to produce coal oil or kerosene for use in lamps had not yet begun.

The general picture presented by these random notes is that of a country depending largely upon the forests for fuel except where population was concentrating and where industry had used up the available supply within an economic distance. Bituminous coal was not uncommon in coastal cities and was in local use in places that were later to prove great coal centers, such as the Pittsburgh, Richmond, and Blossburg districts, but the country as a whole used in a year something less than is now produced in a quarter of a day. We were on the threshold of a great expansion in anthracite mining, and this coal became the dominant fuel in the northeastern portion of the country which held the principal manufacturing districts of the time. The need for cheaper and better fuel was being generally felt and was producing a profound effect upon transportation. It was an important factor in starting the great canal development which gave us 5000 miles of canals. This movement was halted, however, by the more rapid introduction and development of railroads. Railroads, steamboats, and gas works were as yet but small users of fuel in the modern sense. The coke industry and coal-distillation industry for the production of coal oil were to be future developments. Petroleum and natural gas as products of industry were not dreamed of. Steam engines were still novel and limited in total power, and there was no hint of the internal-combustion engine. Wood, bituminous coal, and charcoal were much used without grates. Stoves with grates, burning anthracite, for domestic heating and cooking were a novelty and the subject of much invention.

The practice of numbering patents began in 1833. Of those numbered from 1 to 100 the records of 12 are completely lost because of fire, but of the remaining 88, eight were for cook stoves, heaters, or fireplaces, one for a furnace for warming buildings, one for a vertical boiler, and one for a removable firebox for locomotives. Thus one-eighth of the inventions of the time were in the field of fuels. The removable firebox seems to have been an effort to remedy the disadvantage of the slow ignition of anthracite coal. The inventor claimed "the preparing of a fire in a grate which may be transferred from the place where it is made to the proper place under the boiler of a locomotive." The locomotive was to be serviced with a new live fire at suitable intervals.

There was no lack of keen observation about incomplete combustion, especially of bituminous coal. The smoke nuisance was already old. In the Richmond basin, however, where people usually enjoyed good health, this happy state was credited by the inhabitants to the beneficial effect of mineral fuel.

A little more than one hundred and fifty years ago, fire ceased to be an element. The discovery of oxygen made possible the formulation of a rational theory of combustion. Books of the period of 1833 expressed the chemistry of fuel burning in its newest and simplest elements. The need for an adequate amount of air at the right place and at the right temperature was well understood by the natural philosophers of the time. The split bridgewall to admit supplementary air to burn gases in the combustion space was already old to a few, but these ideas were still novel to the great majority of fuel users. Count Rumford had interested himself in simple matters of heat production, heat transmission, and the design of kitchen equipment, and these subjects were deemed worthy of a place in philosophical transactions. In 1796, while residing in London, he presented $5000 to the American Association of Arts and Science for the biannual award of a premium for the most important discovery or most useful improvement on heat or light made in America.

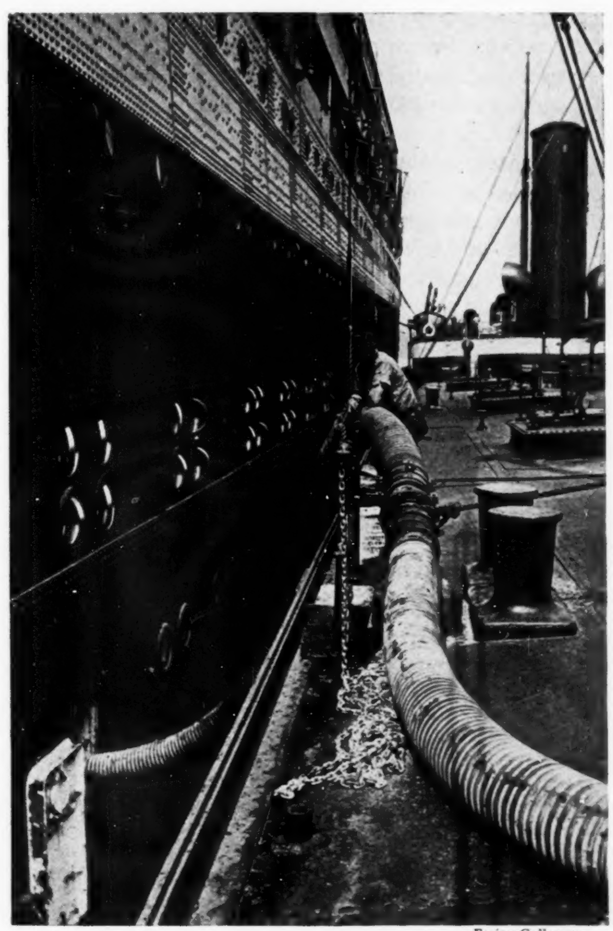
One contestant for the Rumford prize, Marcus Bull, read a paper before the American Philosophical Society on April 7, 1826, entitled "Experiments to determine the comparative quantities of heat evolved in the combustion of the principal varieties of Wood and Coal used for Fuel in the United States; and also to determine the comparative quantities of Heat lost by the ordinary apparatus made use of for their combustion." For a calorimeter Bull used a small room in which the operator could burn fuel in a small stove, the air of the room being heated to a temperature ten degrees warmer than the air surrounding the room. Heat was dissipated from the thin walls of the room, and the length of time that the required temperature could be maintained with equal weights of various fuels was used as a comparative measure of the respective heating values. Shellbark hickory wood was used as the standard of comparison. Awkward as this method of testing would appear today, it is interesting to note that in comparing the relative heating values of seven woods, hickory, oak, beech, maple, birch, chestnut, and white pine, Bull's results put them in the same relative order of merit as we would today with our available information. He was not so fortunate in the order in which he placed anthracite, charcoal, coke, and Georges Creek bituminous coal, which present information would list in the order of bituminous coal, charcoal, anthracite, and coke.

Bull made a claim for the Rumford prize and there was much discussion and criticism of his work. It brought out a number of pamphlets by the interested parties in accordance with the custom of the times. The committee, however, decided against the claim on the ground that the work was not of sufficient accuracy.

The awkwardness of the prevailing phrases, units, and terms of the time make strange contrast with those we use today. In an old cyclopedia of the time, "fuel" is defined as "the pabulum of fire, or whatever receives and retains fire, and is consumed or rendered insensible thereby." Fuels were then classified under five heads, fluid, peat, charcoal, coke, and wood or pit coal in the raw state. Since both wood and pit coal gave a "copious and bright flame," they were classified together. The need for close classification of coals came later.

The performance of steam engines was measured by the effective work performed compared with the amount of fuel supplied, usually measured by the bushel. The true potential value of fuel was masked by all the exigencies of combustion in unfavorable environment and inaccuracies of unit measurement. This led to some controversies that make interesting reading today. The best of the experimenters were often misled.

Anthracite was sold by weight and bituminous coal usually by bulk. Bituminous coal was calculated by the chaldron in the east, by the barrel in the south, and by the bushel at the mine. The number of bushels per ton varied through wide limits. We had (and still have) two weights called a ton, but the chaldron, weighing anywhere from 3360 to 2500 lb, has disappeared, and the bushel of five pecks and tons varying from 36 to 25 bushels no longer vex us. It was the day of the vulgar fraction and of the rule of proportion. Technical quantities were expressed in what seems quaint language today. Heat quantities had been measured by the amount of ice that could be melted, by the rise in tem-



Ewing Galloway

PROGRESS IN THE USE OF FUELS HAS SUBSTITUTED OIL FOR COAL ON MANY STEAMSHIPS

perature of a volume or a weight of water, and in Bull's work by the time a given weight of fuel could maintain a room at a temperature of 10 F above the external atmosphere. The weight of water that could be evaporated from and at 212 F was just coming in as a measure. Not long before this time Rumford had used the terms "abduction," "recession," and "pulsation" where we now use the words "conduction," "convection," and "radiation" in the transfer of heat.

It was not until the report of fuel testing by Prof. Walter R. Johnson in 1844 that tests and reports on fuels begin to have a familiar look to those of us who are interested in fuel technology. Professor Johnson had interested himself in fuel problems for some years as professor of natural philosophy and physics at the University of Pennsylvania. An appropriation made by Congress to the Navy Department in 1841 authorized the Secretary of the Navy to make experiments in the cause of national defense, and Secretary A. P. Upshur instituted an inquiry on fuel primarily on account of the difficulty which had been experienced and the complaints which had been made relative to the qualities of the coals procured for the naval service. Some few experiments on the subject had previously been made under the authority of naval officers but with means and appliances, it was stated, that were little calculated to afford the desired information.

Professor Johnson conducted the investigation at the Washington Navy Yard and made his report in November, 1843. He was ingenious in devising methods, sound in the principles of the day, and was a prodigious worker. More than 40 different coals are reported upon in a 600-page volume, much of the information being good today. Proximate and ultimate analyses were made, evaporation performances recorded, flue gases analyzed, and ignition and clinkering characteristics noted. Gas analyses were made as a matter of interest rather than as a guide to combustion control.

For years English coals had been imported into this country, 90,000 tons in 1833, and these coals did not make a good showing in the tests. The report was called to the attention of the English Admiralty in a letter by a member of Parliament, in which he wrote:

> The late Mr. A. P. Upshur of the United States was strongly impressed with the importance of determining the nature and qualities of the several coals in the United States with a view to their use in the Navy of that Country; and in 1842–43 directed a course of experiments to be made on different kinds of coals of the United States, for the purpose of ascertaining their evaporation powers. I have only this day received from the United States the report of that inquiry, and I have the satisfaction of sending a copy of that report to your Lordship, that you may see the result of that inquiry.
>
> They have decided by direct and practical tests the comparative usefulness of American and English coals as well as the relative value of the former in their numerous varieties; and I submit to your Lordship that a similar inquiry should be instituted into the comparative usefulness of the several kinds of English, Scotch, and Irish coals, with a view of ascertaining the best for the naval steamers of this country.

The letter called attention to the availability of "a public establishment perfectly qualified to apply the requisite direct and positive tests to the coals without delay."

It was in this way that coal testing was undertaken by the Director General of the Geological Survey of the United Kingdom, forming a precedent followed sixty years later by the United States.

It was entirely within the period of the past century that petroleum and natural gas were made available in quantity to the useful arts. The technology of their recovery, transportation, and use were developed within this period.

To these new fuels have been added processed fuels, each of which has a complicated and growing technology. The great industry of processing coal to produce coke, gas, tar, and other products has developed in this period, with something of importance happening in every decade for the past seventy years.

Continuous progress has been made in the manufacture of gas from coal through the whole of the century. It is recognized as one of the great industries based on fuel technology. The production of liquid fuels from coal by using high temperatures and pressures in a most complicated technology has been shown to be possible within the last few years. Another new comer is liquid gas from petroleum with a still younger technology.

Whereas 100 years ago the heating of homes was perhaps the major use for fuel, today industry demands 85 per cent of the fuels used.

The great present uses for fuel are for transportation by railroads, boats, and automobiles; the development of electrical current and mechanical power in power plants; and the recovery and refining of metals, as illustrated by our great steel industry.

In each of these fields, fuel technology occupies an important place. But of all the changes the 100 years have brought, the most far-reaching and astounding has been the development of the internal-combustion engine, burning gaseous, liquid, and solid fuels behind a moveable piston. This prime mover has made possible the subdivision of power in small efficient units, has made practical an individual transportation mechanism, and has given us the ability to fly and to proceed below the water. In these fields lie the romance of fuel technology.

In all of these fields there is a rapidly growing body of published information expressed in the terms of current scientific thought. Much painstaking research using most of the tools of modern science has been brought to bear upon fuel and combustion problems and the results published. Many methods of investigation have passed the pioneer stage and some have standard units and procedures. From all this it has been possible to arrange courses of study of fuels based on fundamentals and worthy of a place in a college curriculum.

The general plane of understanding of fuel problems is rapidly rising. One hundred years ago there was no such thing as a boiler plant running at 90 per cent efficiency. We have such cases now. But to produce any considerable effect in the elimination of waste of fuels, we must look to improved average practice rather than to our few best records. There is evidence that all of our fuels are being used more rationally each year and that the average man, and woman too, knows more and cares more about fuels.

An Appraisal of ECONOMIC FORCES

By L. P. ALFORD[1]

In response to a request, Mr. L. P. Alford, a member of the American Engineering Council's Committee on Economic Balance, presents in this article his personal views by way of interpretation of some of the questions raised by the report published in the April and May issues of "Mechanical Engineering." Mr. Alford's appraisal will lead to a clearer understanding of the Committee's studies.

AMONG the comments offered concerning the report on "The Balancing of Economic Forces," the Second Progress Report of the Committee on the Relation of Consumption, Production, and Distribution of the American Engineering Council[2] are criticisms to the effect that the report is inconclusive and fails to present a program of remedial measures for business instability. These criticisms are reasonable from the viewpoint of the reader. The report does not present detailed conclusions, nor does it give a plan for preventing or minimizing business depressions.

These lacks are also reasonable from the special viewpoint of the council committee. Its members have been at work together for more than two years along a definitely marked-out program. The First Progress Report[3] presented a hypothesis as to the cause of the present business depression. The Second Progress Report, which has occasioned the comments of lacks, analyzes forty causes of business instability and twenty-three suggested remedial plans. The Third Report, which is scheduled for about a year hence, is expected to present the committee's views in regard to remedies. Should any one think that the time allotted to the investigation is too long and the restriction to future depressions too limited, he is requested to consider (1) the magnitude of the task of assembling 40 economic variables into one expression and then solving that expression, and (2) the fact that little if anything can be done to lessen a depression after it has once started. The time for action is before recession has begun.

In this situation it may not be inappropriate for a member of the committee to express his personal views by way of interpretation on some of the issues raised by the report. That much I am glad to do, expressly stating, lest my position be misunderstood, that I am speaking solely for myself, and not as a member of the committee.

The situation in the United States today measured by the facts of current business and industrial performances is discouraging. There are those who believe that the cyclic movements of business are inevitable, and that little can be done to prevent their occurrence or minimize their effects. Accepting this viewpoint at its face value, it is still evident that much of the misery and distress in the present business swing is due to man-made conditions. A natural cycle of economic events can hardly be blamed for acts of betrayal of trust, or criminal speculation, or credit and price manipulations. We can therefore say with positiveness that even if booms and depressions are natural phenomena, we can change and improve the man-made regulations of business, the rules of the game of living.

This thought continued further leads on to the most hopeful feature of the entire situation. The overshadowing cause of the prosperity of 1921–1929 was *intelligent work.* "These great changes in the fortunes of mankind were made possible by the application of science to the work of producing, transporting, manufacturing, and distributing goods." . . . . "Since 1921 Americans have applied intelligence to the day's work more effectively than ever before."

If, during those years of boom, some of the intelligence used in expansion had been used in consolidating the gains achieved, our situation today might have been different. But a depression was necessary to throw abundant creative energy into the channel of economic thinking. The thousands of magazine articles, hundreds of books, and scores of reports that have been made since 1929 are evidence that intelligent work is now being done in this field. Of all facts this is the most encouraging. Good must and will come from this effort, as understanding grows.

Turning now to the report, a few of its many points will be taken up substantially in the order in which they appear in the original document.

Since the report was written there have been a number of astounding revelations of betrayal of trust by men in high financial positions. Such acts of betrayal cannot be too strongly condemned. Any attempt to stabilize business should make such acts impossible, or so hazardous to their perpetrators, that they will not be committed to the hurt of the people.

[1] Vice-President, Ronald Press Co., New York, N. Y. Mem. A.S.M.E.

[2] See Mechanical Engineering, April, 1933, pp. 211–224, and May, 1933, pp. 295–304.

[3] Ibid., June, 1932, pp. 415–423.

No check must be permitted on the application of science to every-day affairs. In particular there must be no restraint on the continued development of machinery and tools, improvement of production processes, substitution of power for hand labor, and improvement of managerial effectiveness.

The disturbances of human relations which these developments and improvements make must be compensated for, but scientific and technological progress must go on unhampered.

Unemployment is a pressing problem. It appears that 35 man-hours of industrial work in 1931 produced as much as 51 man-hours worked in 1923. It appears, further, that the average annual rate of increase of productivity in well-managed establishments is about 4 per cent. Not only is unemployment a present problem but it promises to be a continuing problem. There was a substantial amount of unemployment even in the boom years of 1928 and 1929. Three attacks on this problem appear to be constructive:

(1) Expansion of the production of constructive luxuries and services produced at costs to make them generally purchasable.

(2) Shortening of the hours of labor with high penalties for overtime work.

(3) Unemployment insurance.

Wages have always been a cause of contention between the employed and employing groups. Before the depression the doctrine of high wages seemed to be generally accepted. From 1931 to date wage and salary cuts have been the rule. Purchasing power is dependent upon wage and salary distribution. Thus only one belief seems reasonable; wage and salary earnings must and will increase as an important step in the process of regaining prosperity.

Evidence is accumulating to indicate that the large business and industrial concern is relatively ineffective and that the location of such units in large centers of population is unfortunate. The dissolution of large business and industrial plants and the relocation of the fragments and of new enterprises in small urban and rural communities should be encouraged.

Monopolistic and profiteering price fixing should be banned, and an effort made to bring all prices of goods and services to a level where there can be the freest exchange. Providing of wages and income is not enough to stimulate and maintain buying; pricing must also be fair.

Under our present business economy, and in any situation that can be conceived as possible in the immediate future, the profit motive will be a predominating force. Therefore the opportunity and possibility of earning a reasonable profit must be maintained. At the same time a curb should be placed on speculation. No single step could probably do more to lessen the severity of depressions than to control or prevent unstabilizing speculation.

The money situation is too confused at the moment to hazard comment as to what might be done. We are launched on a procedure of experimentation. It is doubtful if any one knows just what the results of the moves already made and contemplated will be. A single observation seems to be in order. If taking away the workingman's glass of beer was a noble experiment, increasing the price of his loaf of bread is a bold experiment.

The agricultural situation is particularly complex; seemingly it is growing in difficulty for some 2,000,000 persons have gone to the farms during the past three years giving the United States the largest farm population in our history. It is probable that many of the newcomers as well as many others are down to the level of subsistence farming, a condition which as a nation we cannot tolerate for long. At this point the problem of raising and maintaining the standard of American living is particularly acute.

Historically the tariff has been a political football, used for party advantage and as a means of protecting and increasing the profits of politically favored industries. Secondarily it has been a weapon to be used in securing advantages in trade wars and maneuvers. Now a new concept is developing. The tariff should be a tool of conscious social control. This new evaluation of what the tariff is and might be deserves encouragement.

Public construction needs long-time planning. In the very nature of things the decision to build cannot be followed the next minute by breaking ground. Time is needed for surveys, exploration of alternative plans, preparation of final plans and specifications, getting bids, letting contracts, and other necessary work. Long-time planning would carry projects along in good times and have them well advanced or ready for construction when unemployment began to increase. Engineers have advocated this procedure for many years.

Any approach to suggestions for remedies for business instability must be made in terms of a problem of great complexity, on the one hand, and great possible rewards on the other. The peak of production of 1929 must not be thought of as an exceptional maximum. Rather it must be regarded as a record to be equaled and exceeded in providing the good things of life for our people. This favorable situation now prevails: No longer is there any problem of supplying demand. American industry can produce a tidal wave of goods and services, all that can be consumed. Since about 1923 the possibility of supply has been continually ahead of the possibility of demand.

Because of this situation in considering the possibilities of control, of matching production and consumption, we are more interested in rates and accelerations than in quantities. This assumption then is justified: The new planning, whether on a plant, industry, or national scale, must be concerned with rates of production, distribution, and consumption; and the new control will be of rates and rates of change. Stated in this way both the new planning and new control are distinctly engineering problems, capable of solution only by the engineering method.

The Human Side of SMOKE ABATEMENT

By WILLIAM G. CHRISTY[1]

Ewing Galloway

THE MAKING of smoke dates to the time primitive man learned the use of fire, and offensive black smoke probably first appeared with the discovery of bituminous coal in England. As early as 54 B.C. the Britons were apparently acquainted with the use of coal, as at that time the invading Romans found tools and cinders near the old Roman wall in England. The first actual record was in 852 A.D. when the Abbey of Peterborough gave a receipt for twelve cartloads of coal. Originally coal was dug out from the seashore where it had been exposed by waves and tides and was called "sea-coal" to distinguish it from charcoal. It had come into widespread use in England in 1257. In that year Eleanor, wife of Henry III, removed to Tutbury Castle from Nottingham owing to the "unendurable smoke of the sea-cole."

The first smoke legislation came in 1273 when the use of sea-coal was prohibited in England. Even the smiths were obliged by law to burn wood. But despite all laws and ordinances, the use of coal became more and more widespread.

The earliest smoke-abatement association dates from 1306. It was in that year that the nobles and prelates coming to London were greatly annoyed by the increasing smoke and took the lead in getting up demonstrations. Despite the law of 1273, the situation became so bad that in 1307, King Edward I named a "Commission of Oyer and Terminer" to enforce the anti-smoke law. This commission's instructions are quite interesting: "To inquire of all such who burnt sea-cole in the city, or parts adjoining, and to punish them for first offense with great fines and ransoms, and for the second offense to demolish their furnaces."

On the Continent, the first record of an anti-smoke edict was in 1348 when the town authorities of Zwickau, Germany, proclaimed a law that "all smiths working within the walls shall refrain from the use of coal."

The earliest English scientific treatise on smoke abatement seems to have been a small volume addressed to King Charles II in 1661 and published by his express command, entitled: "Fumifugium; or the Inconvenience of the Aer and Smoak of London Dissipated; together with some Remedies Humbly Proposed." The author was the famous diarist, John Evelyn, one of the founders of the Royal Society. He wrote:

> That Hellish and dismal clowd of sea-cole . . . so mixed with the otherwise wholesome and excellent Aer, that her Inhabitants breathe nothing but an impure and thick Mist accompanied with a fuliginous and filthy vapour . . . corrupting the Lungs, and disordering the entire habits of the Bodies; So that Catharrs, Phthisicks, coughs and consumptions rage more in this city than in the whole Earth besides.

He proposed "that by an Act of Parliament this infernal nuisance be reformed."

In 1716 Dr. Desaguliers wrote on a "New Method of Building Chimnies to Prevent their Smoaking." Benjamin Franklin, in 1745, attacked the problem from the point of view of the domestic fireplace. It was in 1795 that James Watt suggested that "cold fuel be introduced behind an incandescent mass." Known as the coking method, this remains today one of the best systems of hand firing bituminous coal.

The House of Commons began appointing "Select Committees" on smoke elimination in 1819. By order of this branch of Parliament, a report of its "Select Committee on Smoke Prevention" was published on

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Contributed by the Fuels Division for presentation at the Semi-Annual Meeting, Chicago, Ill., June 25 to July 1, of The American Society of Mechanical Engineers.

August 17, 1843. This committee held public hearings, one of the witnesses being Michael Faraday, who testified in part:

> The principle upon which smoke . . . may be entirely burnt, is very plain and clear; . . . The cause of imperfect combustion is merely a deficient supply of oxygen to the fuel at a sufficient temperature; whenever a sufficient supply of oxygen at a sufficient temperature is obtained, the whole is consumed.

Although written ninety years ago, this statement of the essential requirements of complete combustion is just as true today.

SMOKE AGITATION IN AMERICA

The earliest known record of smoke abatement in the United States was a suit at law in St. Louis, Mo., in 1864. This was the case Whalen vs. Keith (35 Mo. 87–89). Originally brought before a justice of the peace, the case was appealed to the Missouri Supreme Court which declared smoke to be a nuisance and adjudged damages of $50. Chicago became exercised about smoke nearly sixty years ago. In 1874 the Citizen's Association interested itself in the smoke problem. The first smoke ordinance in America was adopted by the Chicago City Council in April, 1881. It declared that "the emission of dense smoke . . . from any chimney anywhere within the city shall be . . . a public nuisance."

In this same year, W. F. Pollock wrote in an article published in the *Nineteenth Century*, London:

> Every particle of coal which is driven off as smoke, and is not burnt in the furnace or fireplace as flame, is so much good combustible matter lost to the person who has paid for it, and all the labour and time occupied in putting it into the furnace, or on to the fire, is just so much labour and time altogether lost and rendered unproductive.

This remains today the most convincing argument to use in dealing with owners and executives responsible for smoking plants.

It will thus be seen that for more than 600 years, ever since bituminous coal has been used as fuel, there has been a smoke problem. Agitation by those living or sojourning in a smoky atmosphere has resulted in the appointment of thousands of committees and commissions to investigate the problem and recommend remedies. Numerous royal edicts have been proclaimed and hundreds of laws and ordinances adopted regulating the use of fuel and prohibiting the emission of dense smoke from chimneys. But despite all investigations and legislation, the smoke problem is still with us and the agitation continues.

THE HUMAN ELEMENT

The technical features of the smoke problem have very largely been solved. Combustion engineering has kept pace with power generation, heating, and industrial operations. With very few and unimportant exceptions, any such operation can be carried on efficiently, economically, and smokelessly. Equipment can be designed to burn any fuel successfully and smokelessly. Not only can it be designed, but today there is on the market equipment which will burn almost any fuel and perform practically any operation without making smoke. This being the case, why are so many American communities still suffering from excessive smoke? There are, of course, several reasons for this, in all of which the human element has always been a major factor.

ENGINEERING NEEDS PUBLICITY

For steam generation in stationary plants and for most industrial furnaces, engineers have designed and produced fuel-burning equipment which can be operated without smoke. The principal difficulty is that the public often does not realize that smoke abatement is primarily an engineering problem. The bulk of engineering work is not personal service, as is the case with the legal, medical, and other professions. Perhaps for this reason, and also possibly because engineers are often too reticent, the public does not have a very clear conception of engineers and engineering work. Probably the various engineering organizations, both national and local, could improve this situation materially with more of the right kind of publicity. A well conceived and executed policy along this line should impart to the layman a better knowledge of our profession and its functions. Local engineering associations and local sections of national engineering societies ought to have active public-relations committees. The possibilities of what can be accomplished are evidenced by the results obtained by several such committees.

The individual engineer also has an opportunity to give material assistance by taking an active part in civic affairs. Our community problems today almost always involve engineering to some extent. Frequently the public does not realize that the problem is primarily a technical one. This is particularly true of smoke abatement. It might help to rectify this condition if more engineers took part in community affairs.

One of the most persistent fallacies in the public mind is that a smoking factory chimney is a sign of prosperity. This is doubtless due somewhat to thoughtlessness and to the persistence of the old-fashioned idea that smoke is a necessary evil in an industrial community. Numerous instances could be cited but one or two should suffice. Catalogs, sales literature, and even letterheads of manufacturing concerns often have pictures of their plants with clouds of smoke coming from the chimneys. Chambers of Commerce still publish such illustrations to indicate that industries in their towns are busy. Action in photographs of steamships and locomotives is suggested by dense smoke belching forth from the stacks. Our newspapers, magazines, and books frequently contain articles using the same idea. Writing about the Bowery, a well-known New York columnist recently said:

> The Bowery is a human barometer that registers acutely depths of depression, but it is first to register signs of returning prosperity. When the bread line vanishes, smoke from factory chimneys is inevitable. And slowly today the bread line is thinning.

Such illustrations only emphasize the need for more publicity of the right kind about smoke abatement. Engineers could help by calling attention to this fallacy at every opportunity.

REQUIREMENTS OF A SMOKE PROGRAM

Let us consider some of the essential elements of a successful smoke-abatement campaign. The initial step in starting or reorganizing a smoke-regulation bureau in an American community has often been to adopt or revise a smoke ordinance. The author maintains that the primary requisite should be to convince the "powers that be" that smoke abatement is an engineering problem and that the bureau should be organized and operated along engineering lines. Those to whom this idea ought to be sold may include the mayor, city or county commissioners, officials of the city, township or county legislative body, local political leaders, or a combination of any of these. Before any further steps are taken, it is important that those in authority in local or regional government be convinced that the smoke-prevention department should be operated on engineering lines without political interference. It can be done. It was done very successfully some three years ago in Hudson County, New Jersey. It is also advisable to enlist the cooperation of chambers of commerce, merchant's associations, civic and improvement organizations, women's clubs, professional societies, and, most important of all, the publishers and editors of the local newspapers. Such preliminary work is essential for the ultimate success of a smoke-elimination program.

If the officials and organizations mentioned are properly "sold" on an engineering program, there need be no political interference. All too frequently has politics made smoke-abatement campaigns at least partially ineffective. Perhaps the smoke inspectors are chosen in order to discharge political obligations without any regard for their engineering experience or other qualifications for the job. Possibly even the smoke commissioner is not selected on account of his technical ability. One of the most discouraging things is to have politics interfere with the negotiations between a smoke-department executive and an official of a smoking plant. This naturally handicaps the department in its work with other smoking plants. There is nothing so disheartening to a smoke commissioner as to be impotent to do anything about certain plants or buildings which are chronic "bad smokers."

A SALES DEPARTMENT

The smoke bureau of any city or other governmental unit may be likened in some respects to the sales department of a corporation marketing a new product. The commissioner would be the sales manager and the inspectors, engineer-salesmen. Their most important function in dealing with plant operators is to convince them that "it can be done." Plant executives should be "sold" on the idea that modern fuel-burning equipment is really an investment which can soon be amortized by the saving in fuel. The efficiency of stokers, oil burners, and pulverized-coal equipment is of course well known to engineers and most executives of large plants. Officials of many plants still think of the cost of such equipment as an expense. They do not seem to realize the improved boiler or furnace operation that could be obtained in their own plant. The most convincing argument to use is that smoke is a sign of waste and that its elimination will result in higher plant efficiency.

Several years ago, in an address delivered before the Citizens' Smoke Abatement Conference in St. Louis, O. P. Hood, chief mechanical engineer of the United States Bureau of Mines, gave some "Practical Suggestions on Smoke Abatement." One paragraph of that address is so apropos to this phase of the subject that the author takes the liberty of quoting it verbatim:

> As far as the technical phase of it goes, the solution of the problem can be found. The more difficult part of the problem is the human problem. One of the strange things about this problem is that we are rarely troubled with our own smoke. It is our neighbor's smoke that troubles us. We are all quite willing to have our neighbor regulated. The difficulty comes, in this human problem, of being willing to be regulated ourselves. In any smoke-abatement movement there always has been, and always will be, opposition. There are people who insist that it will injure business, and, of course, we are a very "business" nation. Without arguing about it, let us see what the net result is in places where some success has been achieved. The net result has been, in almost every case, that the objectors have finally been converted; that they find when they face the real problem with an "I must do it" that the result is satisfactory. It has not cost as much as they have feared, and the cost is entirely made up by better performance. It is the problem, therefore, of the smoke-abatement organization, whatever form it may have, to get that idea across to the business man. He must first get over his nervousness, over the feeling that this little item affecting about 2 per cent of his yearly costs is going to be so seriously attacked that it is going to be a serious thing in his business. In round numbers, the cost of production of power for manufacturing and work of that sort is, I am told, about a 2 per cent item, and that is one reason why so little attention is given it.

The author is firmly of the opinion that a smoke-abatement campaign conducted along educational and cooperative lines will give best results. With a program of this character, a certain amount of propaganda is very useful. There should be no "soft pedaling" of smoke's evil effects and the damage caused by it. Anything that can be done to make the people of a community "smoke conscious" will eventually be of material assistance in actually stopping smoke. Spreading this message effectively is a problem in mass education. The radio and printed literature may be used to good effect. The daily newspaper is probably the best medium. The effects of this publicity can actually be noted in the attitude of those responsible for smoking chimneys. Plant executives who oppose or are indifferent to the work of the smoke bureau will later become interested and cooperate in the campaign.

Probably the most important element of success in a smoke-abatement program is the cooperation of the offenders themselves. The wielding of the big stick, the attempt to "pull the law on somebody," will not stop much smoke. It should be done by a combination of tact and good judgment, good sensible advice, and demonstration that it can be done. There are always

some people who are ready to say, "It can't be done." The vast majority of them can be convinced by inspection of plants where it was done and interviews with officials of such plants. The sales methods previously outlined are very helpful in this respect. When a smoke inspector calls to register a complaint against a smoking chimney, he must give sound technical advice of a constructive nature. Mere complaint is not sufficient. He must be able to tell that man what he should do. He must be able to give good advice, reasonably practical under the conditions. This is essential to the success of a cooperative program.

HEATING PLANTS

Heating boilers and furnaces were originally designed to burn anthracite coal. Notwithstanding the fact that bituminous coal was the prevailing fuel used in large sections of the United States, heating boilers and furnaces of the same design were sold for use in these regions. For the larger heating plants, the down-draft boiler was developed for bituminous coal. In recent years, the so-called "smokeless boiler" was designed and marketed for soft-coal firing. Both of these types can be operated with very little smoke *provided* they are fired carefully. Here again the human equation is a big factor as boilers of these types will smoke if not given careful attention. Any such equipment which depends on the proper functioning of the human element is never satisfactory from a smoke standpoint. Despite the newer designs mentioned, domestic heating boilers designed for anthracite are still being sold for hand firing with bituminous coal.

One of the first heating units specially designed for a particular fuel was the gas-fired boiler. It is only in the past two or three years that there have been placed on the market heating boilers designed for burning oil and for stoker firing with bituminous coal. With all the improvements in design, large numbers of heating boilers and furnaces are still being sold and installed with little regard for the kind of fuel to be used. In far too many instances, no attention whatever is given to combustion and to the consequent smoke performance. Undoubtedly this condition is due mostly to competition. This is one of the reasons why a smoke department must require permits for such equipment and have regulations covering details of the installation. It is time that the boiler furnace or firebox be considered as a separate and distinct piece of equipment and not as a part of the boiler.

One reason for the smoky condition of many American cities is that the manufacturers and distributors of fuel-burning equipment have paid too little attention to how it will be operated or to the fuel that will be used. The same applies to the producers and distributors of fuel. As a consequence, equipment is being installed every day which smokes from the time it is put in operation. In other words, in addition to the older plants which are now polluting the atmosphere, new ones are daily being added to the list of "bad smokers." This of course refers only to those districts where no permits are required and hence where there is no supervision of new installations by a smoke department.

RAILROADS

In most American cities, the railroads are a large factor in the smoke problem. While most of the larger locomotives are now stoker fired, switch engines and many used on local trains are still hand fired. Many of the Eastern roads still have in service engines with fireboxes designed for anthracite coal. There are devices, including air-induction tubes, ring blowers, and special grates which are of great assistance in getting better combustion. Elimination of railroad smoke depends to a considerable extent on the human element. Quite a number of men have a part in handling a locomotive at different times during its cycle of operations. The master mechanic and his force of mechanics take care of all repairs and maintenance. A fire builder, under supervision of an enginehouse foreman, builds the fire. Very often a water tender looks after the engine before it is moved out of the round house, this latter being done by a hostler. There may be an engine watchman who keeps up steam until the crew comes aboard. After the run there may be fire cleaners, fire knockers, hostlers, and water tenders having a hand in taking care of engines.

Notwithstanding that a locomotive is a moving power plant, with high rates of combustion and a rapidly varying load, that the crews have strict time schedules to meet, numerous signals and crossings to watch in addition to all duties of power-plant operation, that there are stringent requirements of the roads themselves and of numerous regulatory bodies, and hundreds of laws and ordinances to be observed, the railroads usually do a better job of smoke abatement than other classes of plants. Results can be accomplished by having the railroads operating in a district form a smoke-abatement association. Most of the smoke work is done by the roads themselves, with the smoke department furnishing the incentive and making a daily checkup. Despite the fact that engine crews are largely "on their own," the railroads, in normal times, have better supervision than other classes of fuel users except possibly the larger industrial companies.

FLOATING EQUIPMENT

Most of our larger cities have a marine smoke problem. In the case of larger vessels in port, boilers are being operated at light loads with a third assistant or a watch engineer in charge. If coal fired, steam air jets will be of great assistance in getting better combustion. When oil fired, smoke is usually due to carelessness or inattention. When a boat is getting ready to sail, there is always a tendency to hurry the operation too much. Great improvement can naturally be made by taking more time. In any case, the human element is the principal factor and better supervision will get results. Metal signs, calling attention to smoke regulations, have proved of value. Such signs will attract the attention of even firemen or engineers who cannot speak

English. In such cases the chief does the interpreting. The best effect is obtained by hanging the sign in a prominent place in the fireroom immediately upon arrival, removing it before sailing.

In the design of the smaller vessels, including ferries, tugs, lighters, grain and coal loaders, etc. combustion seems to have had minor consideration. Much of the boiler equipment was designed for anthracite, while now bituminous coal or oil is being used. In far too many cases the hull is designed first and power-plant equipment selected to fit the space available and for its similarity to equipment used in older vessels. It would seem desirable for some government department to supervise the combustion chamber as they do the safety of the boiler. Steam air jets have been of great assistance in many instances. Here again the human equation is the chief factor as jets must be conscientiously used to be effective. This is a field where much constructive work is needed. A few tugs will often pollute the atmosphere of a whole harbor.

The various marine interests in a district can be brought together in a smoke association and the smoke work handled by the organization. The author believes that the Marine Smoke Association, of Hudson County, N. J., is the first and only group of this character in this country. This association is now two years old and has done some excellent smoke-abatement work. The improvement in smoke conditions in New York harbor is due largely to the work of the Hudson County group.

Along the Eastern seaboard there has grown up a custom of employing alien firemen. In some cases these men do not speak or understand the English language. The author knew of a tug operating in New York harbor on which the fireman spoke only Spanish and the engineer only English. Instructions were given to the fireman by the sign language. Needless to say the elimination of smoke on this tug was quite difficult to obtain.

CONCLUSIONS

This paper does not attempt to cover all the various phases of the smoke problem nor the many different applications of fuel-burning equipment to processes and industries. There are still too many industries where rule-of-thumb methods are used and where there is vital need for good combustion engineering. One example of this is the ceramic industry, although natural-gas and oil installations in recent years have cleared up many "bad smokers." Another source of much trouble for a smoke department is the burning of rubbish and garbage on dumps in congested centers of population. This of course is not a combustion problem at all but is really a police job. Administration of a smoke department requires great resourcefulness and the ability to secure the cooperation of all concerned.

One of the first things to do in starting a smoke campaign is to clean up any city or county plants which may be smoking. A smoking chimney on the city hall is naturally quite a handicap to a city smoke department. In some localities, the most flagrant offenders have been United States government buildings or vessels. This is a very difficult situation. The government is not amenable to local ordinances and the responsible official may be in Washington.

The human factor enters into every phase of smoke abatement. The human-relations problems are often more numerous and more difficult than the technical problems. There are available on the market various types and makes of oil burners, mechanical stokers, and powdered-coal burners which are highly efficient and can be operated smokelessly. With a plant equipped with latest type of fuel-burning equipment, instruments, and accessories, it is still necessary to have it operated properly and intelligently. Rates of fuel feed and air supply must be regulated according to the load. Adjustment of air on forced- or induced-draft jobs must be watched carefully and kept in proper proportion to the fuel. The service and maintenance must not be overlooked. Owners of heating plants all too frequently do not realize the necessity of proper inspection and maintenance of mechanical equipment. The operator of the plant should, of course, be familiar with all the details of his equipment. Instruments are very helpful to give visual and recorded information. Every plant should be equipped with smoke indicators so that the operator can observe smoke conditions constantly. Clear stacks will be the rule if the entire operating personnel is on its toes and is "smoke conscious." There must also be cooperation on the part of those responsible for using steam or having a part in any way connected with the operation of the fuel-burning equipment.

In order to attain the desired goal, the aim of a smoke department should be to secure the cooperation of all concerned. This includes not only the fuel users but architects, engineers, contractors, fuel distributors, and manufacturers of equipment, as well as officials of various government units. Smoke abatement should be sold as thoroughly as possible to the public. The economy of better combustion is the most convincing argument. By means of publicity and propaganda, the public, and particularly those concerned with the burning of fuel, should be made "smoke conscious." The attitude of the plant management is usually reflected down the line. If a plant is reasonably well equipped, a "smoke conscious" management is the best assurance of clear stacks.

Finally, a word about continuity of smoke-abatement efforts. Mr. Hood, of the Bureau of Mines, has many times emphasized the importance of a continuous program. During the past year there have been some new examples which prove the soundness of this argument. Several cities with an excellent record of smoke abatement have abandoned or greatly curtailed the smoke department. Within a few months conditions were very bad again, the efforts of years being practically lost. Municipal water departments continue from year to year as a matter of course. Even with changes of administration and economy programs, the engineers are kept on the job and the water department functions. The American public needs to be convinced that pure air is as essential as pure water and that the job of maintaining pure air is just as important.

An Engineer's View of
INVESTMENT BANKING REFORMS

By GREGORY M. DEXTER[1]

In a previous article that appeared in the May issue, the author took engineers and bankers to task for practices in connection with investment banking that are not in the public interest. The proposal is made in the present article that investment bankers should set up a bureau which would make available to the public, at nominal expense, a rating for every security as it comes into the market.

ANYBODY who will take the time to read the proceedings of the Investment Bankers Association of America for just one recent year, will turn away from them with admiration for the excellent work which that association is doing through its committees and board of governors. Unfortunately, however, this work does not reach the general public except indirectly through its influence on the association membership. One committee may criticize the circular of an investment banker on a proposed issue as misleading, as not containing all pertinent data, and even as not including such a fundamental piece of information as a balance sheet. The banker may ignore the criticism. Many bankers are not members in the association. The clientele of the banker who issues such a circular accepts, in its ignorance, the statements it contains at their face value and buys the security described although many might not have done so had their attention been drawn to its defects. The highly technical ability of engineers, auditors, and lawyers is frequently necessary to find such defects.

HOW CERTAIN BANKERS FEEL

A summary of some of the important recommendations by various committees of the Investment Bankers Association of America, from the annual proceedings for 1930, 1931, and 1932, shows the great difficulties involved in putting a sound issue of securities on the market in such a way that the public gets the necessary facts.

The Money and Credit Advisory Special Committee apparently despairs of any constructive measure beyond an "inventory plan" which is a report, segregated as to classes of securities which bankers have for sale, designed to prevent flooding the market. The Irrigation Securities Committee places the responsibility for the unsatisfactory condition of irrigation securities squarely upon bankers and state commissions who did not "investigate properly the economic soundness of the districts to be financed." The Industrial Securities Committee stresses the need for not being "too sanguine in boom times and too pessimistic in difficult times," and the need for "making a thorough examination, not only into the financial condition of the company and its probable future, but into the ability and integrity of the management." The Public Securities Committee pleads for "merely downright good business practice" in circulars issued, as to the "correctness and fullness of facts and information given, but even more important, in the implications to be drawn from their relative prominence." It comments, in another report, on poor circulars which are "erroneous, indefinite, inadequate, poorly arranged, incomplete, and incorrect." The Public Securities Committee, in still another report, urges frank and fearless methods and the open discussion of controversial questions. It argues for simple corporate and financial structures so that the relative value of the various securities of a public utility may be correctly appraised. The Real Estate Securities Committee recalls that, in 1923, it warned against responding to excessive valuations or higher costs in placing mortgage bonds, yet the warning went unheeded a great many times.

The preceding is tacit admission that through lack of teamwork and inability to enforce discipline, investment bankers are having the same troubles that most trade organizations have. Obviously, something more has got to be done. The choice seems to lie between more laws and more strenuous voluntary action.

The report of the field secretary of the Investment Bankers Association in 1931 indicates that more laws are probably not the solution. He outlines his efforts to change or stop legislation inimical to the best interests of the members of his association. He gives numerous examples of proposed laws which, with one exception, would probably do more harm than good. They are all aimed at raising the standards of integrity and ability of investment bankers. Note, however, that the Investment Bankers Association appears to have taken no constructive action other than to modify or stop them and to continue their present voluntary cooperation among the limited group in their membership. They do not place sufficient emphasis upon their obligation to protect the public against not only some of their own members but, also, the underwriters and quacks who do not belong to their association.

[1] Scarsdale, N. Y.

A RATING BUREAU FOR SECURITIES

Investment bankers might well set up a bureau which would make available to the public, at nominal expense, a rating for every security as it comes into the market. This would have to be corrected, from time to time, as conditions required. Something of this sort is already being done by some of the investors' services but at a cost which is beyond the reach of most persons. Similar impartial service, at nominal expense, is given by numerous bureaus in many industries. The amount of trustworthy information which can be obtained through them is astounding. The Anthracite Institute, for example, maintains a testing laboratory where equipment is extensively examined to determine "all factors which would in any way influence its desirability to its ultimate consumer." The American Gas Association has a similar service. One of its recent publications claims that it has saved the general public a great deal by maintaining quality standards through this depression. Consumers Research, Inc., attempts to furnish unbiased recommendations, for a nominal fee, on the general run of merchandise such as soaps, vacuum cleaners, and the like. The United States Department of Commerce publishes a directory of commodity specifications so that a buyer may describe exactly what he wants with some assurance that he will get it. It is a mere listing, but it contains more than 500 pages. An investor, therefore, should be able to get similar information about any stock or bond with as little difficulty and as little expense.

PROBLEMS INVOLVED IN AN ADVISORY SERVICE

Many difficulties are involved in an advisory service maintained by investment bankers and their associates, such as the magnitude of the work, the necessity for absolute impartiality, lack of uniform accounting, thorough investigations, and refusal of corporations to cooperate in supplying reports at proper intervals. But these do not seem insurmountable in the light of the increasingly better work over a period of years which has been done by the Associated Press and the New York *Times* when it comes to reporting news. Carl W. Ackerman, dean of the School of Journalism, Columbia University, in a recent report said that "within the limits of time and human efficiency the press is developing greater independence and accuracy day by day and year by year." He added that "as a business and industry the newspapers as a whole have been better managed than banks, industries, and government. There have been fewer mergers and failures—no scandals and financial losses..." He believes what bankers and business men should also believe, that the rights of the public are superior to those of the individual, for he says that "some day in the not distant future the rights of the public represented by the reporter will be recognized as superior to the rights of the official or corporation, and the press will have more accurate and more reliable sources of information." Things have come to a pretty pass in this country if bankers and business men are so hopelessly involved that they cannot set up a bureau of financial information which will be accurate and non-partizan. Even in religion and education there are but a few churches and universities and schools of technology which have managed, to their great credit, to maintain platforms where a man may say what he honestly believes to be the truth without fear of reprisals.

The New York *Times* of October 7, 1932, quoted the president of the American Bankers Association as defending bankers from the charges leveled against them. He is said to have claimed that the "large volume of foreign securities floated in this country came into existence as a result of economic forces that were irresistible in their power." A banker, however, has no more right to offer such an excuse than an engineer when a dam is swept away by an unprecedented flood. Investigation always shows that more care in design and construction would have prevented the loss of the dam. That is why many important engineering projects have boards of review. That is why investment bankers need a board of review. There is ample testimony to prove that such a board would have prevented much of the fiasco, for example, of Latin-American and the Kreuger investments.

INSTITUTE OF INTERNATIONAL FINANCE

The Institute of International Finance is basically the same as the advisory bureau on investments for which this article pleads. The Investment Bankers Association of America organized it in 1926 as a fact-finding bureau on foreign securities. Its reports, heretofore, have been of such a technical nature that they have not had general public interest. Its existence was scarcely known except to the initiated few. The committee in charge decided in 1931 that widespread lack of public information, and the frequency of confusing or erroneous reports on foreign situations, made it desirable that the Institute direct its efforts to this important public service in order to prevent needless sacrifice of values by many holders of foreign securities. Its reports now give, in non-technical terms, information on the cause of financial difficulties of foreign countries, their present financial status, and remedial measures that are being undertaken. The information in any report is immediately available to the press and thereafter to any person at the nominal cost of 15 cents, to cover printing and postage. Any owner of a foreign bond may become a member of the Institute for $5 a year and any investment banker for $15 a year.

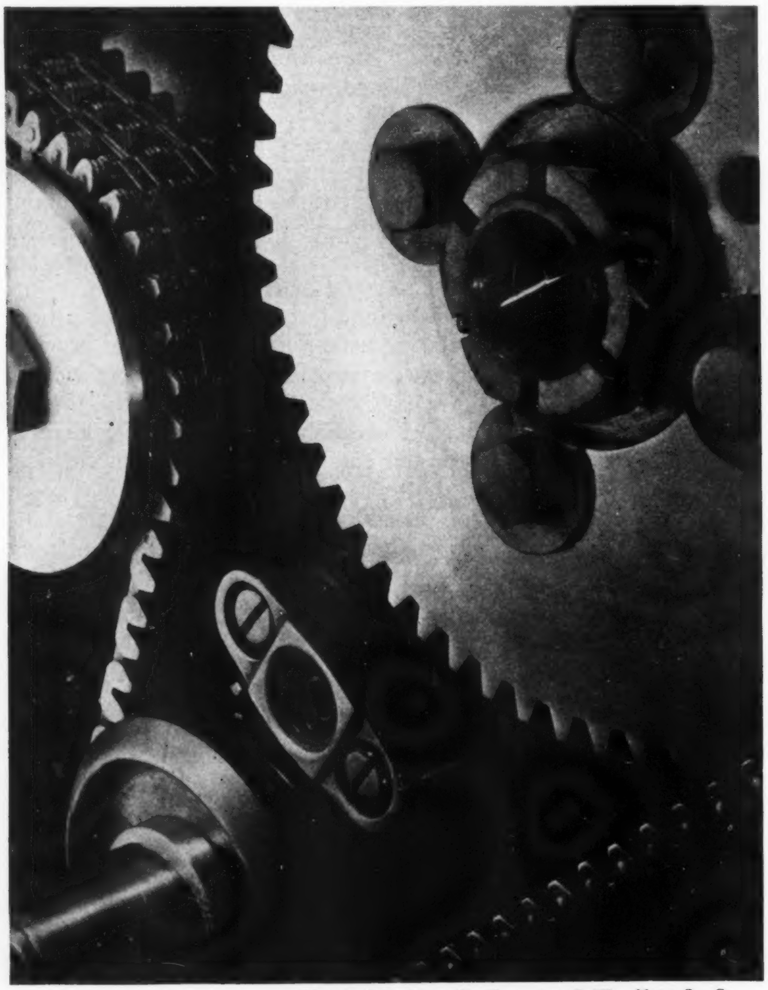
The preceding description is taken almost verbatim from a report of the Foreign Securities Committee of the Investment Bankers Association. It shows that bankers are working toward the ultimate goal of a real advisory board on foreign securities which will pass on the worth of individual issues in addition to general conditions. Yet the New York *Times* reports recent testimony in Washington to the effect that the director and assistant director of the Institute of International Finance claimed greater freedom of action in their scholastic capacities than as officers of the Institute.

Some difficulty has been met in the attempt to get a hearing for the views expressed in this and a preceding article. The passing months have brought increasing evidence that they are sound, however unpalatable. The New York *Times* of February 21, 1933, quoted Prof. Walter Rautenstrauch, of Columbia University, before a group meeting of the American Institute of Banking, as recommending the establishment of "an industrial and commercial fact-finding bureau from which the public may obtain full information on any business, the securities of which are offered for sale." Frank A. Vanderlip, in the *Saturday Evening Post* of January 7 and 14, 1933, recommended that the Stock Exchange set up a banc of three independent judges, not personally engaged in business, of judicial temperament and unswervable purpose, men with a great store of business experience and impeccable business records. He wanted, in addition, an "investor's union" operated by a "group of public-spirited men, selected solely on their record of integrity and good judgment."

FINANCING THE PROPOSED ADVISORY BUREAU

The proposed advisory bureau can probably be made self-supporting. Endowment funds will be necessary in its early life. Investment bankers will have to make the initial gifts but they should have little difficulty in getting additional subscriptions from life-insurance companies, large industrial organizations, public utilities, and even philanthropists. Appeal for funds can be made not only on the basis of self-interest, such as savings in cost of investigations which are necessary for the purchase of securities, but also on the broader basis that here is a work that means much in the elimination of waste. Some executives will recognize that the standards of their own corporations are almost identical with those which this bureau will undoubtedly adopt. They will be glad to develop, by cooperation, the broader market for their securities which its approval will give. Foundations have been heavily endowed for far less important work. Once started, the continuance of the bureau will depend upon the development of broad public confidence in the absolute impartiality of its recommendations, upon appropriate publicity, and upon such reasonable charges that even the purchaser of a $100 bond will not feel that he can dispense with its advice.

Its board of directors must include not only the highest type of investment banker but leaders drawn from such diverse fields as engineering, accountancy, public utilities, industrials, law, labor interests, social service, and education. They must be noted for their integrity and ability. Such a board will set a standard as to impartiality in the reporting of facts without fear or favor, and as to thoroughness of investigation which will assure the continuance of the bureau.



TIMING SPROCKETS AND SILENT CHAIN

Photograph by Anton Bruehl, courtesy Cadillac Motor Car Co.

PLYWOOD

As a Building Material

By PHILLIP S. HILL[1]

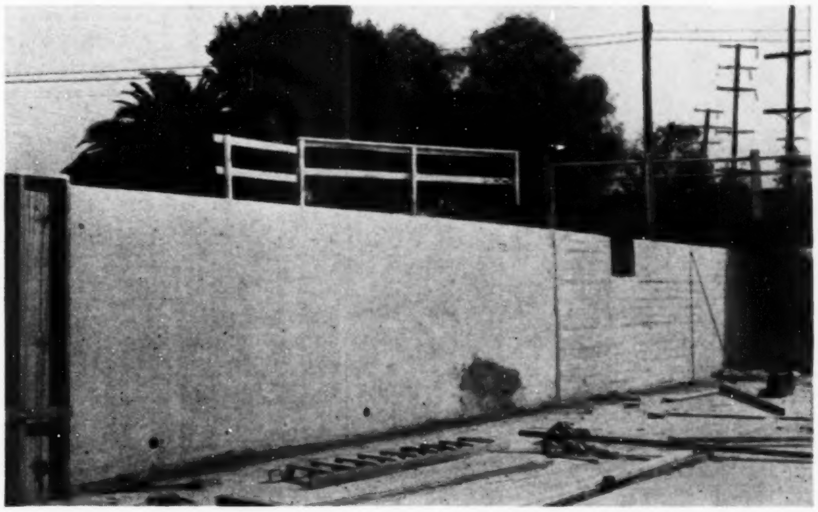


FIG. 1 SECTION OF REINFORCED CONCRETE STORM DRAIN

(Note particularly the contrast in the surface of the concrete produced by plywood forms and that by forms sheathed with ordinary lumber.)

FOR many years plywood has been used to a relatively small degree, in the construction of buildings. Plywood panels, made principally from hardwood veneers, have had wide usage for interior requirements such as wainscoting, partitions, and cabinet work, but it is only in recent years that plywood has been available at a cost that greatly increases its use as a building material.

PLYWOOD FORMS FOR PLACING CONCRETE

The field of building construction has opened up an extensive market for plywood. Improved methods of mixing concrete and more exacting specifications for the forming have forced engineers and builders to seek out and use new materials. Inasmuch as skilful carpentry is essential in the building of low-cost concrete forms, the introduction, a few years ago, of plywood lumber for concrete forms was timely.

A specially fabricated and oil-treated plywood is necessary for concrete forms, and as a result of careful research with glues and actual testing in the field, concrete-form plywood is now readily available. Because the material can be used from six to ten times, the cost per square foot of contact area is comparatively low. The size and thickness of plywood panels for forms depend entirely upon the design of the structure to be built, and as the cost of building forms is a sizable item in the total building cost, careful study should be given to the layout and design of the forms themselves. If this is done, the use of plywood will not only result in smooth, durable concrete, but will save from 20 to 40 per cent in the direct labor of making up and stripping forms.

The advantages of plywood for concrete forms are briefly as follows:

(1) Plywood panels serve as sheathing lumber and lining combined, making strong non-leaking forms with a minimum lineal footage of joints. Plywood does not shrink or swell, so these joints remain tight, thus retaining in the forms the necessary water for proper hydration. The plywood form reduces to a minimum the chance of honeycombed surfaces on the finished concrete and greatly reduces the number of board marks, fins, and other irregularities. (See Fig. 2.) In addition to other economies, the almost complete elimination of rubbing means a saving of from 4 to 12 cents per sq ft of concrete surface. The smooth exposed surface resulting from the use of plywood forms makes painting easy and economical and often eliminates the necessity of cement plastering. Figs. 1 and 2 show the unusually smooth surface that can be obtained on concrete structures by the use of plywood forms.

(2) The laminated construction of plywood offers a material which is stronger and more rigid for its weight than steel, solid wood, or fiber, and these qualities remain unimpaired by exposure.

(3) Large plywood panels cut at the mill to sizes as specified can be made up into forms quickly with only a fraction of the fitting, sawing, and nailing necessitated with the usual lumber forms. (See Fig. 3.) Only a comparatively few nails are required to secure the panels to the framing, and nails may be driven close to the edges without splitting the plywood.

Engineers and contractors have been quick to see the advantage, from the standpoint of cost, of using dimension plywood in the forms for beam and girder sides and bottoms as well as one-piece column sides. Much plywood has been successfully and economically used during the last three years on several outstanding projects, and the full development of its use is only awaiting the return of building construction to a more nearly normal scale.

PLYWOOD WALLBOARD

Despite the scarcity in construction of new homes during the past four years, the development and use of plywood as wallboard have persisted and in larger volume each succeeding year. Necessary repairs and remodeling of present dwellings have afforded a large market in which plywood as an all-wood wallboard is fast becoming recognized as one of the best materials for these purposes. As a matter of fact, several concerns engaged in the business of building new houses are now conducting exhaustive scientific tests on plywood to determine its suitability for permanent walls and ceilings instead of plaster.

One of the most widely used forms of plywood wallboard consists of three sheets or veneers of selected old-growth Douglas fir, laminated, with the grain of the inside or center ply at right angles to the grain of the two outer plies. Under enormous hydraulic pressure, the three plies practically become one unit through the agency of a water-resistant glue which

[1] Chicago District Manager, Harbor Plywood Corporation, Chicago, Ill.

Contributed by the Wood Industries Division for presentation at the Semi-Annual Meeting, Chicago, Ill., June 25 to July 1, 1933, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Abridged.

FIG. 2 PIERS IN HIGH-LEVEL BRIDGE AT CLEVELAND, OHIO, MADE WITH PLYWOOD FORMS

forms a bond of high shear strength. After setting, this glue bond is actually stronger than the wood itself. The result is a split-proof, non-warping, all-wood wallboard which resists shrinking, swelling, bulging, and sagging. This wallboard has the advantages of the finest fir lumber, yet it is available in convenient wallboard sizes and has greater structural strength than either plain lumber or wallboard substitutes. The shear strength of this 3-ply wallboard is almost the same parallel to as across the grain, it can be split only with difficulty, and it resists fracture by accidental impact.

This 3-ply wallboard is available in standard wallboard sizes 32 and 48 in. wide and 6 to 12 ft. long. Because of its light weight and ease of handling, and also because of the large range of sizes, savings of 10 to 40 per cent over ordinary lumber are possible in handling and labor costs. It costs no more than many of the composition boards. Being sanded to satin smoothness, this wallboard presents a perfect surface for numerous types of finish and decoration, including the conventional plaster, paint, and stain finishes, as well as the most modern and artistic plastic finishes.

The plywood panels are nailed directly to studding and joists and the painters can start in the moment the carpenters are finished. Unlike plaster jobs, walls and ceilings of plywood wallboard are unaffected by the ordinary settling of a building. There is no waiting for plaster to dry and no risk of damage to floors or soiling of trim.

The standard 3-ply wallboard is clear and sound on one side with a reject back and, in order to balance the panel construction, is sanded on two sides. Panels of $^1/_4$ in. net thickness are suitable for walls in basement and attic rooms, garages, summer cottages, poultry houses, etc. while for walls of more permanence in principal rooms and particularly for ceilings $^3/_8$-in. 3-ply and occasionally $^1/_2$-in. 5-ply panels are recommended.

Plywood wallboard lends itself particularly well to panel effects. In new construction it is best to use furring strips of $^1/_2$ in. net thickness nailed to the studding before applying the panels, as then no refitting of door and window frames is required, and standard trim may be used throughout. The cost of the furring strips is very small.

The plywood panels are nailed directly on to the studding and joists. No space need be allowed between the panels, because the shrinkage or swelling of this type of wallboard is negligible. Side-wall panels should be placed with the grain of the wood running vertically. When finish nails are used, they are driven in with the heads flush with the panel surface, and the molding or battens are applied over the joints.

Paneled ceilings often look better if additional molding strips are used lengthwise and crosswise to give the effect of smaller panels. This affords the opportunity of nailing the ceiling panels to each joist and placing a molding strip over each line of nail heads, giving the effect of 16-in. panels, and with cross-molding strips to appear as though panels 24 or 48 in. long were used. This can, of course, be varied in large or small rooms, or to fit in with the location of lighting fixtures. Beamed-ceiling effects are easy to obtain by first placing the solid or boxed beams, fitting the ceiling panels in between the beams.

With the development of several methods of joint treatment, it is now easy to secure flush wall finishes with plywood wallboard by applying the board directly to the studding and joists, or in the case of modernizing or remodeling jobs, by nailing it over the old plaster or other wall surfaces.

A new joint filler has been developed primarily for use with plywood wallboard. This is non-shrinking, hardens to about the density of the wood itself, is tinted to match the natural

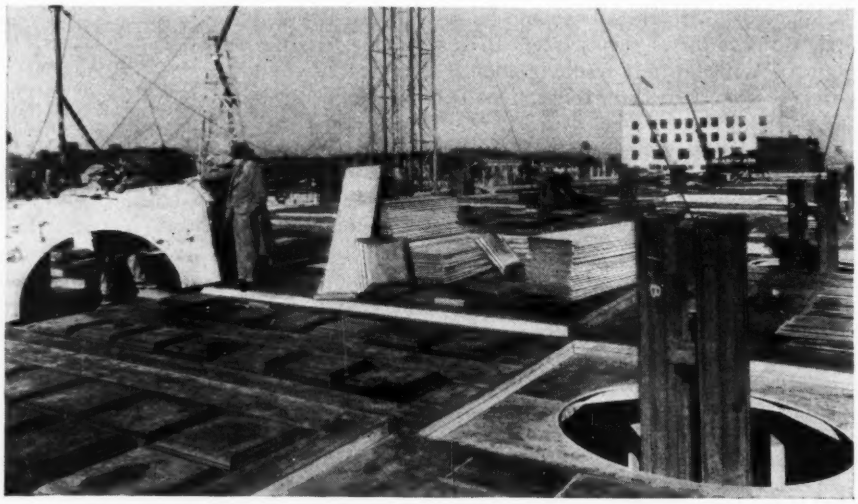


FIG. 3 FORMS FOR THE FIRST SLAB IN THE ILLINOIS TRACTION TERMINAL BUILDING
(The form design calls for an interesting use of plywood in combination with metal pans. This plywood, including the drop-heads, was fabricated to exact size at the factory.)

color of the wood, comes in dry powdered form, and is easily mixed with water. The application of this filler to the joints is a simple task for any skilled workman, and the result is a flush wall or ceiling suitable for paint, enamel, or plastic finishes.

Another way to produce a flush wall is to glue a wooden spline in the joints. The wallboard is fastened in position with nails at least $^1/_2$ in. from the edge. The edges of the wallboard are spaced $^1/_{16}$ in. apart by using a 4-d nail as a gage. A wooden spline which has been lightly glued is then tapped into the joint. (See Fig. 4.) To cut the spline flush with the wallboard, the entire length is scored close to the wallboard surface with a chisel. It is then broken off and sanded down to an even surface. This method provides a continuous wood surface.

Still another way to produce a flush wall is to set a piece of molding into the joints. The edges of the abutting panels are equally rabbeted to half the thickness of the wallboard and a strip of flat molding 1 to 2 in. in width is glued into place. This molding is then dressed down to a flush finish with the wallboard surface.

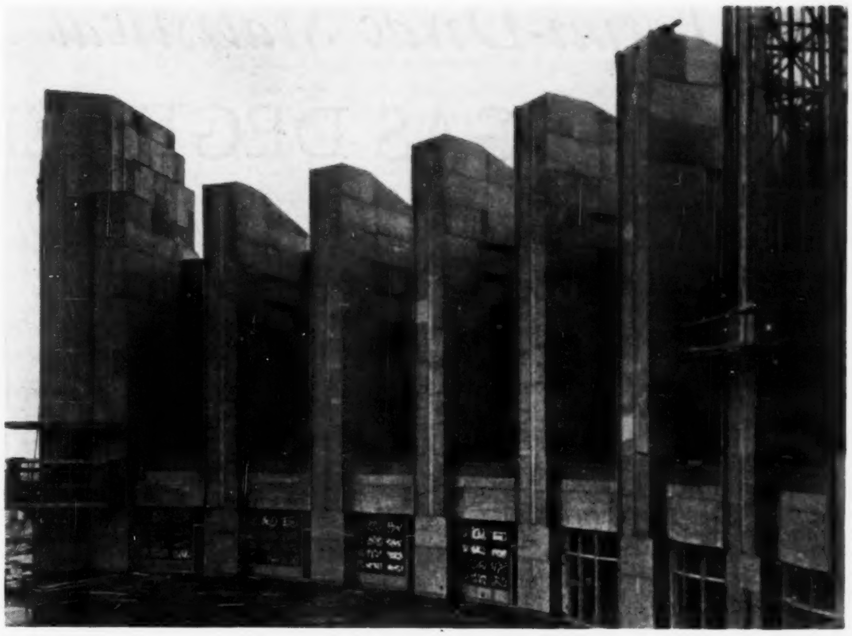


FIG. 5 PYLON CONSTRUCTION, HALL OF SCIENCE, A CENTURY OF PROGRESS EXPOSITION, SHOWING EXTERIOR PLYWOOD WALLS

An attractive wall effect is produced by using a V-groove joint. The vertical edges of the panels are smoothed with a plane and then beveled one-half the thickness of the panel. By butting the panels tightly together an inverted "V" joint results.

SUB-FLOORS AND SHEATHING

For sub-flooring or for flooring to be covered by carpet or linoleum, plywood offers a combination of economies and other advantages not otherwise obtainable. The large panels save approximately 50 per cent in flooring and sub-flooring labor, by minimizing the work of sawing, fitting, joining, and nailing. The great reduction in lineal footage of joints, with the fact that plywood joints will not open, lowers air leakage, and the plywood is approximately 10 per cent more effective as an insulator than ordinary lumber.

Used as sub-flooring, plywood contributes greater structural strength than ordinary materials. The $^5/_8$-in. 5-ply unsanded plywood is most frequently used in constructing sub-flooring.

The opposite edges of sub-floor panels which run at right angles to the joists should be grooved to a depth of $^1/_2$ in. and to a width of $^1/_4$ in. Into this groove on one side of each panel is glued a 3-ply spline, $^1/_4$ in. thick and 1 in. wide, which forms a tongue. When two adjacent panels are driven tightly together, this type of joint prevents any vertical movement at the edges of panels in the span between joists. The other two edges of sub-floor panels may be square without matching because adjacent square edges form a tight butt joint directly over a joist member.

Finally, plywood floors and sub-floors tend to prevent squeaking. Such floors can be soundproofed and made resilient by placing a layer of sound-deadening material upon the sub-floor. Two-by-four sleepers then rest on this material.

PLYWOOD SHEATHING

For virtually the same reasons that recommend it for sub-flooring—labor-saving, insulation, and greatly increased

(*Continued on page 386*)

FIG. 4 PLYWOOD INSTALLED AS A FLUSH CEILING

(The splines which have been glued into the joints between the panels will be cut off flush with the surface and sanded down.)

The Fermi-Dirac Statistical Theory *of* GAS DEGENERATION—III

With Some Applications to Electronic Phenomena in Metals

By VLADIMIR KARAPETOFF*

VI—INTERPRETATION OF SOME PHENOMENA ON THE BASIS OF THE DEGENERATE ELECTRON GAS

A picture of the degenerate electron gas permeating a piece of metal and obeying the Fermi-Dirac statistics has been drawn. This has been devised to account for some well-known features of behavior of metals. It remains to show that such a system, consisting of an ionic lattice and a degenerate electron gas, may be expected to respond, at least qualitatively, to external physical forces as actual metals do. Formulas and numerical data will be found in the references quoted at the beginning of this article. It is desired here merely to prepare the reader for understanding more rigorous mathematical articles on the subject. A critical reader no doubt will notice in what follows that the detailed structure of the ions constituting the metal lattice has not been considered. No thoroughgoing explanation of actual facts may be expected on such a one-sided basis, and the Fermi-Dirac statistics in the form treated in this paper can be looked upon only as a first approximation to a more adequate theory.

(*A*) *Photoelectric Effect.* Equation [33] gives the minimum frequency of incident light at which the fastest electrons are barely able to penetrate the surface "wall" of the metal. As the frequency of the incident light and the corresponding energy per photon increase, slower electrons are accelerated beyond the surface, while the fastest electrons have some excess kinetic energy by means of which they can move away from the surface. The sharp limit of energy, AB in Fig. 4, leads to the expectation of a sharp photoelectric threshold independent of temperature, and this is in accord with the actual facts.

(*B*) *Cold Discharge.* Electrons may be drawn out of a piece of metal by making it the negative electrode of a condenser and producing a strong electrostatic field. Electrons are then "pulled out of the surface" and attracted to the positive electrode. The theory of the emission, that is, the relationship between the strength of the applied field and the electronic current density, may be deduced by first assuming a suitable distribution of retaining potential (Fig. 6) and then computing its modification by the applied voltage. From this, the number of electrons which can penetrate through the new wall may be found.

The formula deduced on these principles provides a curve between the field intensity and the emission current of the same form as experimental curves, only the order of magnitude of the voltage is different. For example, for pure tungsten an appreciable current may be obtained experimentally at a field strength of a few megavolts per centimeter, whereas the theoretical formula requires 20 to 30 megavolts per centimeter. In other words, actual discharge is produced at much lower voltages than those required by the theory.

A possible explanation may be found in the fact that a geometrically perfect surface, with a uniform distribution of lines of force abutting on it, is different from an actual physical surface, with slight irregular projections and depressions. In fact, the arrangement of metal atoms on the surface is not known. It is reasonable to assume a much denser electrostatic field at the raised portions and a reduced field at depressions. This means that with a given total voltage, local field intensities actually produced are much higher in places than those computed on the supposition of a perfectly smooth surface. In other words, the general formula may be approximately correct, only the relationship between the field strength at the surface and the total applied voltage must be computed to correspond to the actual and not an ideal surface.

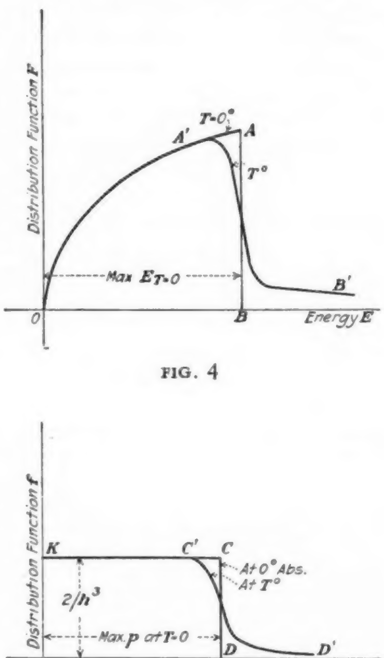


FIG. 4

(*C*) *Thermionic Emission.* In thermionic emission, when a piece of metal is at a high temperature, the conditions differ from cold discharge in two respects: (1) The electron gas is not completely degenerate, the modifications in the distribution functions being represented by the lines $A'B'$ and $C'D'$ in Figs. 4 and 5. (2) Only a low voltage need be applied to remove the liberated electrons from the metal surface; beyond a certain limit, the effect of this voltage upon the emission proper is negligible (saturation current).

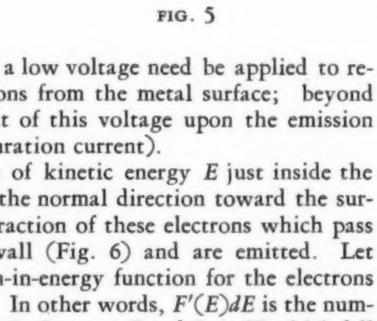


FIG. 5

Consider free electrons of kinetic energy E just inside the metal surface, moving in the normal direction toward the surface. Let $D(E)$ be the fraction of these electrons which pass through the potential wall (Fig. 6) and are emitted. Let $F'(E)$ be the distribution-in-energy function for the electrons falling upon the surface. In other words, $F'(E)dE$ is the number of electrons with energies between E and $E + dE$ which fall from within, per unit time, on a unit area of the surface. F' is

* Professor of Electrical Engineering, Cornell University, Ithaca, N. Y.

used instead of F to distinguish this function from that discussed in section (j). The emission current density is then

$$U = e \int_0^\infty D(E)F'(E)dE \qquad [34]$$

Computations for $D(E)$ depend upon the assumed shape of the wall (Fig. 6); in determining the fraction of electrons reflected back from the wall inside the metal, those electrons are sometimes considered as waves, in accordance with the principles of wave mechanics. $F'(E)$ can be determined from the Fermi-Dirac statistics. In fact, actual integration can be performed, using the distribution function $f(p)$ described in section (k). The resulting formula is of the form previously known from other considerations, and one which accounts in a satisfactory manner for the shape of experimental curves.

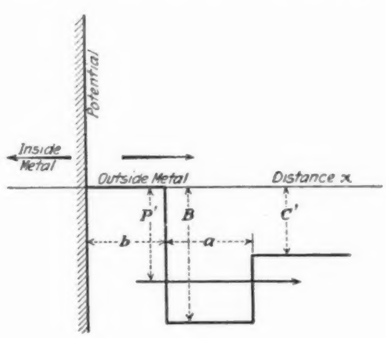


FIG. 6

The presence of even slight impurities at the surface may radically change the rate of electron emission by modifying the ionic lattice. The theory is in a position to account for these changes in a general qualitative manner. After all, with the shape of the wall as a variable, widely differing mathematical results can be obtained, and the aim of the theory is to choose a shape which is of general validity under widely differing conditions.

(D) *Magnetic Susceptibility of Alkali Metals.* As explained in section (e), each spinning electron is equivalent to an elementary magnet. When an external magnetic field is applied to a piece of metal, some electrons must become oriented in the direction of the field, others in the opposite direction. Since by assumption the electron gas is totally degenerate, all the "lower" cells in the momentum space are occupied; this means that for each electron whose axis is "up" there is one with an identical velocity of translation whose magnetic axis is "down." On first thought the total contribution of the degenerate electron gas to the magnetic susceptibility of a metal must therefore be zero. However, this is not so, for the following reason:

When an electron is oriented in a magnetic field, its total energy, say E, is slightly modified thereby. For one half of the electrons it becomes $E + \Delta E$, for the other half $E - \Delta E$. Similar to the representative momentum space previously considered, a representative space in energy values may now be imagined, with its concentric shells, each one of which corresponds to a definite amount of energy. When ΔE is sufficiently small, an electron which previously was, say, in the mth shell, will now not fit either into the $(m + 1)$ nor $(m - 1)$ shell. This means that in place of a single electron gas there are now two coexisting but separate and oppositely polarized gases. For each of these two gases a separate representative space must be imagined, and such a reasoning as was followed at the beginning of this paper must be repeated. This will lead to equations similar to Equation [11], only with $(E + \Delta E)$ and $(E - \Delta E)$ substituted for E. Thus the total number of electrons in the "parallel" gas is slightly different from that in the "anti-parallel" gas.

Taking this difference of the numbers of oppositely polarized electrons and multiplying it by the magnetic moment per electron (a quantity known from entirely different considerations), gives the total magnetic moment of the electron gas. The final expression, deduced under some simplifying assumptions, is positive and proportional to the strength of magnetic field H; it is independent of the temperature of the metal. The factor by which H is multiplied represents the paramagnetic susceptibility of the electron gas which thus is found to be independent either of H or of the temperature.

The experimentally determined susceptibility of a metal is due not only to that of the electron gas but of the ionic lattice as well. The contribution of the ions may be of two kinds: The ions themselves may become oriented in the magnetic field and some of the electron orbits within each ion may be modified. It so happens that in alkali-metal ions the first factor is absent, as is evidenced by the effect of a magnetic field upon the spectrum; that is, an alkali ion is magnetically neutral and does not turn in a magnetic field. The second effect is always diamagnetic, because the orbital electrons, being similar to elementary currents, always place themselves in such planes as to oppose the applied external field.

Thus the actually measured susceptibility of an alkali metal should be smaller than that computed for the electron gas alone. The fact that there is a satisfactory agreement between the computed and measured values (better than the mere order of magnitude) is considered to be an argument in favor of the Fermi-Dirac statistics. Because the measured susceptibility of alkali metals is independent of temperature, the electron gas which they contain must be in a state of complete degeneration. If it were a perfect gas, its susceptibility would obey the so-called Curie law and would be enormous at low temperatures.

(E) *Electric Conductivity.* The reader is advised to re-read section (h) to refresh his memory on the concept of the mean free path of electrons and its variation with temperature.[6] Consider a cylindrical metal rod to the ends of which a difference of electric potential has been applied, so that there is a current through it. Let the longitudinal axis of the rod be chosen as the X-axis. In addition to an irregular motion of electrons due to their zero-point energy, there is now a general drift of electrons along the X-axis. Because of this drift, the former distribution functions F and f are inadequate to express fractions of the total number of electrons possessing various energies and momenta. In particular, it was shown that f was a symmetrical function of $v^2 = v_x^2 + v_y^2 + v_z^2$, where v is the total velocity of an electron and v_x, v_y, v_z are its components parallel to the three coordinate axes. Now v_x becomes a special or preferred direction of motion so that f must depend upon it in a different manner from that in which it depends upon v_y and v_z.

On the assumption that the departures from the "static" f are small, the new distribution function f' may be written in the form

$$f' = f(v) + v_x f''(v) \qquad [35]$$

Here f is the previously derived distribution-in-momentum function and $f''(v)$ is a small correction. Equation [35] is an empirical assumption justified by the results rather than by a priori reasoning.

Without an applied electromotive force, the function f remains constant in time, in spite of collisions between electrons and atoms. Similarly, when a moderate current is flowing through the metal and its temperature remains constant, the inner state of the metal, to the best of our present knowledge, remains unchanged. This means that the new function f' must

[6] T. J. Webb, "A Review of the Theory of Metallic Conduction," *Chem. Rev.*, vol. 7 (1930), p. 139.

also remain constant in time, in spite of the added drift along the X-axis. The conditions are different from those in a material gas containing some ions, when an electromotive force is applied to it of a value below the ionizing potential. In the latter case, the ions are rapidly swept to the electrodes, so that unless new ones are produced (say by ultra-violet light or by X-rays) the initial distribution changes with the time.

Consider again the momentum space with the electrons placed in various cells, only let the individual cells now be much larger, so that each cell contains a considerable number of electrons. By assumption, the general distribution of the electrons in such large cells remains stationary, although individual electrons move from cell to cell as their momenta change in direction and magnitude, due partly to collisions and partly to the acceleration caused by the applied difference of potential. The happenings in the actual lattice space within the metal and in the representative momentum space may be considered simultaneously. The unknown function f'' in Equation [35] is to be determined by the condition that f' remains constant in time in spite of the collisions and of the acceleration due to the applied voltage.

Formally, the mathematical deduction is the same no matter what form of the distribution function f is assumed. In fact, the general method of determination of the conductivity of a metal from the distribution function of its electron gas was given by Lorentz before the advent of the Fermi-Dirac statistics. The particular form of f enters only in the final integration. Therefore, only the general trend of reasoning, without the mathematical details, will be given here.

Consider an interval of time, small compared with the mean time, between some two consecutive impacts of an electron; also fix in mind a particular cell in the momentum space. During this interval of time some electrons (that is, the ends of their momentum vectors) will leave the cells, and others will enter. The electrons which leave the cell do so for two reasons: (*a*) Their velocities are increased due to the acceleration caused by the external field, so that the ends of their vectors move to cells in another concentric layer, more distant from the origin. (*b*) Their velocities are suddenly changed in direction, although not in magnitude, due to collisions with positive ions of the lattice. The vectors of momentum are then shifted to other cells in the same shell.

Similarly, those vectors of momentum which move into the the cell under consideration during the same small interval of time do so for two reasons: (*c*) Some come from layers nearer the origin when the electrons accelerated by the external field acquire just the proper magnitudes of momenta. (*d*) Others come from some other cells in the same shell, due to sudden changes in the direction of velocity because of collisions with positive ions. It remains to express analytically the condition that

$$(a) + (b) = (c) + (d) \quad \ldots\ldots\ldots\ldots [36]$$

The computation of the number of collisions in various directions is somewhat involved but the final result is quite simple, namely

$$f(v) = (l/v^2)(eG/m)(df/dv) \quad \ldots\ldots\ldots\ldots [37]$$

where l is the mean free path, G the intensity of the electric field, and m the mass of an electron.

Consider, now, a cross-section of the cylinder normal to its axis. Each electron which crosses this surface during unit time contributes to the current; if the contribution of the electrons traveling, say, from left to right is considered positive, that of the electrons moving in the opposite direction will be negative. Knowing the distribution function f', or more exactly its unsymmetrical part f'', the net current density through the cross-section can be computed. Dividing this current density by the field strength G gives the electric conductivity g of the metal; it is as follows:

$$g = (8\pi/3)(e^2l/h)(3n/8\pi)^{2/3} \quad \ldots\ldots\ldots\ldots [38]$$

Since the conductivity of pure alkali metals is known, this formula may be used to estimate plausible values of the mean free path l and the number of electrons per unit volume n. The results are considered to be more reasonable and consistent, and in better agreement with experimental values, than those obtained by a similar reasoning using a classical distribution function f deduced for perfect gases.

(*F*) *Thermal Conductivity*. Consider again a cylindrical conductor, as in the case of electric conductivity, only instead of a difference of electric potential let a steady difference of temperature be maintained between its ends. Let the flow of heat be uniform and steady and let it be attributed to the flow of kinetic energy associated with the electrons toward the colder terminal. By analogy with the preceding case, an unsymmetrical supplementary distribution function f'' may be determined which is to be a measure of a one-sided drift of electrons.

There are two difficulties in this method of attack: (1) The distribution function depends not only upon the velocities of the electrons, but upon their positions along the cylinder as well, because of differences in temperature. (2) A drift of electrons in one direction must, generally speaking, be equivalent to an electric current. Actual experience does not indicate that a flow of heat is accompanied by an electric current. The theory by which these two difficulties have been overcome in a plausible manner will not be discussed here since the reasoning has nothing to do with any particular form of distribution function, whether based on the Fermi-Dirac statistics or on any other. Substituting the distribution function f, based on the latter statistics, in the final result, the following expression is obtained for the heat conductivity κ:

$$\kappa = (8\pi^3/9)(k^2lT/h)(3n/8\pi)^{2/3} \quad \ldots\ldots\ldots\ldots [39]$$

k being the so-called Boltzmann constant (see Appendix) and T the absolute temperature. As in the case of the electric conductivity g, the expression for κ contains two unknown constants, l and n, and the value of the result given above depends largely on being able to use in it reasonable values of these constants in order to obtain the right order of magnitude for κ.

(*G*) *Ratio of the Two Conductivities*. The best conductors of electricity are also the best conductors of heat, and this is a plausible reason for attributing both conductivities to the same cause, viz., the motion of free electrons within the metal lattice. In 1853 Wiedemann and Franz announced the following empirical law: At a given temperature, the ratio of the thermal and electric conductivities is the same for all good solid conductors. This law has been found to hold approximately true for a number of pure metals at ordinary and high temperatures. At high temperatures the thermal conductivity is independent of the temperature, whereas the electric conductivity varies inversely as the absolute temperature. Therefore, L. Lorenz, in 1872, supplemented the Wiedemann-Franz law to the effect that the ratio of the thermal and electric conductivities is proportional to the absolute temperature. This relationship also is approximately true for several metals.

These two empirical laws follow directly from the expressions for the two conductivities just quoted; namely, Equations [38] and [39] give

$$\kappa/g = (\pi^2/3)(k^2/e^2)T \quad \ldots\ldots\ldots\ldots [40]$$

showing that the ratio of the two conductivities depends only upon two universal physical constants, k and ϵ, and is proportional to T. The two unknown quantities l and n cancel. The agreement between the theoretical ratio computed from Equation [40] and that obtained from measurements is quite good for a number of metals, at least at ordinary and high temperatures. This agreement is considered a strong argument in favor of the Fermi-Dirac statistics. Of course, there are serious difficulties yet to be overcome; for example, the disagreement at low temperatures, notable departures for some metals even at ordinary temperatures, and the fact that dielectrics transmit heat relatively much better than electricity. Probably the mechanism of heat conduction is much more complex than the mere drift of free electrons.

(*H*) *Intrinsic Difference of Potential Between Two Metals.* In Fig. 7, pieces of two different monatomic metals are shown in contact, in this particular case silver (Ag) and potassium (K). The number of atoms per unit volume in either metal is proportional to the ratio of its density to the atomic weight. It follows that silver contains more atoms (and consequently more electrons) per unit volume than potassium. According to Equation [19], the zero-point kinetic energy of electrons increases with their number per unit volume. Consequently, the swiftest electrons in Ag are moving at higher velocities than those in K.

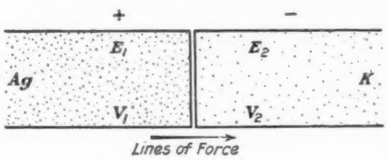


FIG. 7

Call the kinetic energy of the fastest electrons in the two metals E_1 and E_2, respectively, and let the interiors of the metals be at electric potentials V_1 and V_2. The difference of potential $V_1 - V_2$ is brought about by itself as soon as the metals are placed in contact, because of the necessity of maintaining an equilibrium between the two samples of electron gas of different characteristics. Let one of the fastest electrons cross the boundary from the silver to the potassium. It must slow down to the velocity of the fastest electrons in the latter metal. Since the direction of electrostatic lines of force is from left to right, such an electron would be moving in a direction opposite to that of its natural motion. Consequently, it will be automatically slowed down and its potential energy increased accordingly. Contrariwise, should one of the fastest electrons in the potassium cross over into the silver, it would be automatically accelerated by the difference of potential to the velocity of the fastest electrons in Ag.

Thus the existence of an intrinsic difference of potential between two metals is a natural consequence of the assumption of a degenerate electron gas in both. The relationship explained above may be expressed by the equation

$$\epsilon(V_1 - V_2) = E_1 - E_2 \quad \text{[41]}$$

which states that the work done by the intrinsic difference of potential in moving an electron from K to Ag increases its kinetic energy from E_2 to E_1.

It should also be stated that the intrinsic difference of potential cannot be measured, nor is it the same as the contact or Volta electromotive force between two metals. Its existence has to be postulated as a corollary to the idea of the electron gas, where the state of the latter changes along a composite conductor.

The foregoing relationship is not based on any particular form of electronic statistics, except perhaps for the assumption of a maximum finite velocity. Granting the Fermi-Dirac theory to hold true, E_1 and E_2 may be computed from Equation [19] and $V_1 - V_2$ determined. Thus, indirectly at least, the statistics under consideration will be either more firmly established or receive a setback in proportion as the idea of an intrinsic difference of potential finds its confirmation or is refuted in future measurements and theoretical investigations.

(*I*) *Thermoelectric Phenomena.* The three fundamental thermoelectric phenomena are as follows:

(*a*) Thermoelectric Current. Let an electric circuit consist of two conductors made of different metals, welded at both ends, and let the joints be kept at different temperatures. Then even without an externally applied electromotive force there will be an electric current in the circuit, due to an internal electromotive force whose magnitude and direction depend only upon the nature of the conductors and upon the temperatures of the two junctions.

(*b*) Peltier Effect. The junction point of two different conductors absorbs or liberates heat, depending upon the direction of an electric current in it.

(*c*) Thomson Effect. In a homogeneous conductor, different portions of which are maintained at different temperatures, an electric current causes at each point a definite liberation or absorption of heat.

All these phenomena are separate from the liberation of heat known as the Joulean or i^2r loss, and are characterized by the following relationship between the heat and the current: If heat is liberated at a point in the conductor with one direction of the current and the corresponding volume element is heated thereby, then with a current in the opposite direction the same element of volume will tend to absorb some heat from outside and is cooled.

Here again it is necessary to imagine different ionic lattices in different portions of a non-homogeneous circuit, with electron gas in different states of pressure and concentration. For an equilibrium it is necessary to postulate concentrated or distributed intrinsic electromotive forces which keep balance between two portions of electron gas in two different metals or in two different portions of the same metal maintained at different temperatures. We may now remove the electron gas and replace the intrinsic electromotive forces by fictitious storage batteries. Depending upon the direction of the current, some of these batteries will be charging, others discharging. This corresponds to a local absorption and liberation of energy respectively. With a reversal of the current, the places at which energy is absorbed or liberated also interchange their functions, and this agrees with the nature of thermoelectric phenomena.

Here again the general qualitative picture is compatible with any form of electron-gas statistics. Assuming the Fermi-Dirac statistics to apply, values of the Thomson and Peltier effects have been computed and they prove to be of the same order of magnitude as those measured. Besides, the Thomson effect comes out to be proportional to the absolute temperature, and this relationship is found experimentally to be true over a wide range of temperature.

The Fermi-Dirac statistics is only a few years old and the number of its applications to various problems in physics is steadily increasing. It would be useless for the purpose of this paper to try to bring these applications up to date. If the author has succeeded in explaining the fundamental assumptions upon which the theory is based and in showing its possibilities in accounting quantitatively for several groups of phenomena in metals, his aim has been accomplished.

The foregoing study of the subject was made as part of an extensive investigation into the structure of matter, in connection with research on dielectrics supported at Cornell University by the Detroit Edison Company. Sincere thanks are due to Mr.

Alex Dow, the president of the company, and to Mr. C. F. Hirshfeld, chief of research, for their sympathetic and broad-minded encouragement of this and other fundamental theoretical studies. An interpretation of the latest achievements of pure physics and chemistry in terms which engineers can understand will be a potent factor in bringing about important improvements in the applied art of electric power generation and distribution in which the supporters of this research are interested.

APPENDIX

A DERIVATION OF THE BOLTZMANN CONSTANT k

The constant k which enters in Equations [12] and [13], and in many other fundamental formulas of gas statistics, is a quantity which was introduced in the classical thermodynamics and may be derived as follows: Let dQ be the amount of heat communicated to a gram-molecule of a perfect gas; then

$$dQ = c_v dT + PdV \qquad [42]$$

where c_v is the specific heat at constant volume, T the absolute temperature, P the gas pressure, and V the volume of the gas. The first term on the right-hand side represents the increase in the internal energy of the gas due to a rise in temperature, while the second term represents the external work done. Assume work and heat to be expressed in the same units so that no conversion factor is needed in front of PdV.

The expression on the right-hand side is not a perfect differential, but becomes one after division by the integrating factor T. Thus

$$dS = c_v dT/T + PdV/T \qquad [43]$$

where the quantity

$$dS = dQ/T \qquad [44]$$

is known as the increase in the entropy of the gas. The reader may refresh his memory on the significance of entropy by looking up, say, the Carnot cycle in some elementary book on thermodynamics.

The fundamental equation of the perfect gaseous state is

$$PV = RT \qquad [45]$$

where R is a universal constant, provided that V refers to one gram-molecule of the substance. Substituting the value of P/T from Equation [45] in Equation [43]

$$dS = c_v dT/T + RdV/V \qquad [46]$$

The right-hand side of this equation is readily integrable, so that dS is a perfect differential. This means that the entropy S characterizes a state of gas and that an increase in the entropy between any two states is a function of the characteristics of these two states only and not of the path between them or the external work done. In this respect dS differs fundamentally from dQ, because the latter contains the term PdV which is not a perfect differential.

With the development of the kinetic theory of gases, based upon the concept of collisions among molecules and bombardment of the walls of the containing vessel, another definition and interpretation of entropy gradually gained foothold, namely the idea that in some manner the entropy of a state characterizes the relative probability of that state of gas. Without going into the details, the general reasoning may be stated as follows: Let the different portions of a quantity of gas be initially at different pressures and temperatures and let these be allowed to equalize. With a random motion and irregular collisions of molecules, a strictly permanent state (microscopically speaking) is inconceivable. However, the actual successive states, meaning by this combinations of instantaneous positions and velocities of the individual particles, fluctuate about a certain average or most probable combination.

Each particular state of a gas may be realized in a number of ways. Therefore it is possible to speak of mathematical or thermodynamic probability of a state, meaning by this the number of ways in which it may be realized by interchanging individual molecules. Thus there are more probable and less probable states; also, there is the most probable state and the average state. It is known from thermodynamics that the entropy increases during an irreversible process. On the other hand, an equalization of pressures or temperatures means a change from a less probable to a more probable state. Hence, in general, when the probability of a state increases, the total entropy of the substance also increases.

However, entropy is not proportional to the probability and the two vary in a different manner. The combined probability of two independent events taking place concurrently is equal to the product of their single probabilities. For example, if Mr. A spends on the average one third of his time in a given city, the probability of finding him there on a given day is $^1/_3$. It rains in that city one day in eleven. Hence the probability that it will rain on a given day is $^1/_{11}$. Now, the probability of finding Mr. A in that city on a rainy day is $(^1/_3) \times (^1/_{11}) = {}^1/_{33}$, provided that Mr. A's movements from city to city are not influenced by the occurrence or non-occurrence of rain.

More generally, if the probability of an event is $p_1 = f_1/t_1$ and the probability of another totally independent event is $p_2 = f_2/t_2$, the combined probability, that is, the probability of the two events taking place concurrently, is

$$p_{1,2} = f_1 f_2 / t_1 t_2 \qquad [47]$$

In these expressions, f_1 and f_2 are the numbers of favorable events, and t_1 and t_2 are the total numbers of events. Any one of the f_1 events may be combined with any one of f_2 events, so that the total number of combined favorable events is $f_1 f_2$. Similarly, the total number of events is $t_1 t_2$. This proves formula [47]. This formula may be readily extended to any number of independent events, giving a more general formula for the total probability p_t of a complex event:

$$p_t = \Pi p_i \qquad [48]$$

the symbol Π signifies "product."

In application to the kinetic theory of gases, let a given quantity of gas be divided into groups of molecules, and the probability p_i of the state of the ith group determined separately. The term probability is used here in a thermodynamic sense, that is, the number of ways in which a particular combination of coordinates and momenta may be realized. The combined probability p_t for the whole quantity of gas is then expressed by Equation [48].

On the other hand, theory and experience show that entropy is additive and not multiplicative in character; that is, if the entropies of the separate portions of a gas at a certain instant are s_1, s_2, etc., the total entropy is

$$S = \Sigma s_i \qquad [49]$$

It will be seen at once that Equations [48] and [49] may be satisfied simultaneously by putting

$$s_i = k \log p_i \qquad [50]$$

(*Continued on page 389*)

Mechanical Developments in
MUNICIPAL SANITATION

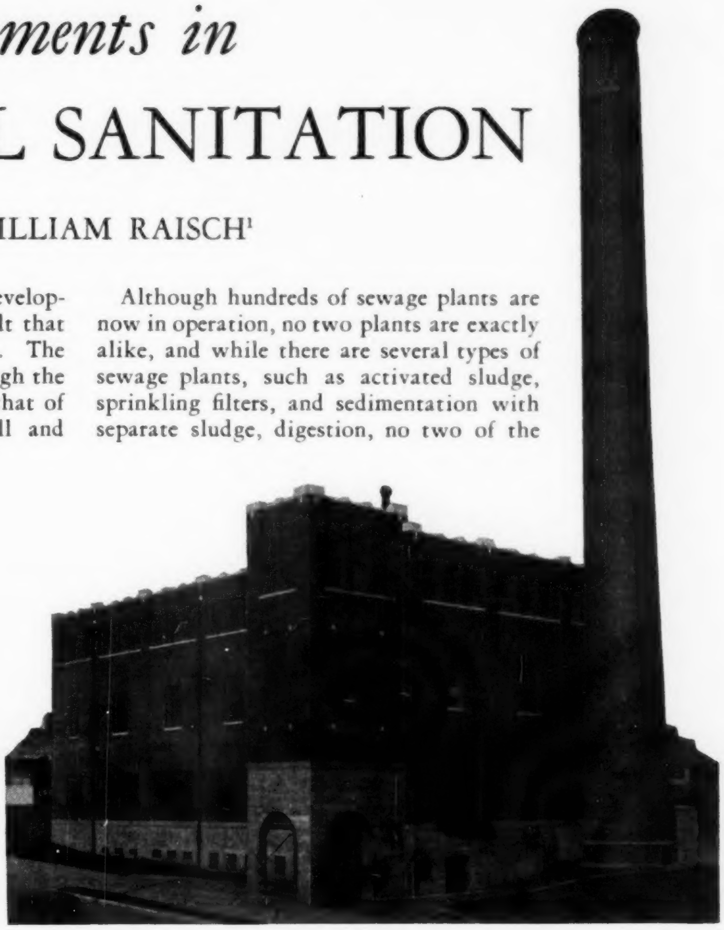
By WILLIAM RAISCH[1]

FOR more than fifty years civil engineers have been developing the art of municipal sanitation with the result that this work is now becoming highly specialized. The progressive steps in sewage treatment have passed through the fields of chemistry and biology and are now entering that of mechanical engineering. While sanitation work will and should remain under the direction of civil engineers, mechanical and chemical engineers can contribute much, for without wholehearted cooperation on the part of each group, the work will not progress with the rapidity it deserves.

A recent survey made by the National Committee for Trade Recovery shows that there are 5996 cities, towns, and villages in this country having populations in excess of 1000 that do not have facilities for sewage treatment. Garbage disposal has also been neglected and many fairly large cities still follow the practice of dumping or hog feeding. Both problems are of utmost importance. Eventually every city and town will possess sanitation works but on account of present economic conditions their introduction will suffer some delay. Gradually, however, the educational work of the newspapers, health authorities, and conservation societies is beginning to take hold. More people have been brought to a realization of the importance of the subject during the last five years than in the fifty years preceding. Many state boards of health have been instrumental in having laws passed which give them full authority to compel cities and towns in their states to construct sanitation plants. They realize, however, that present financial conditions make it difficult to raise money and in some instances have granted extensions of the time limits originally specified for completion of the work. These conditions can only be temporary and with the first sign of improvement many of these projects must be released.

In an average sewage-treatment plant of today the mechanical apparatus and appliances represent from 35 to 50 per cent of the total cost of the plant. Twenty-five years ago the mechanical features amounted to very little, probably less than 10 per cent of the total construction cost. The day is not far off when 75 per cent of the cost of these plants will be that of mechanical equipment, the remainder representing the cost of the buildings and structures required to accommodate the apparatus. With the introduction of these mechanical appliances it is becoming possible to construct plants on considerably smaller plots and consequently in areas where heretofore such construction was out of the question. Many sewage- and garbage-disposal plants are now located within business and residential sections without depreciating the value of the adjacent property.

Although hundreds of sewage plants are now in operation, no two plants are exactly alike, and while there are several types of sewage plants, such as activated sludge, sprinkling filters, and sedimentation with separate sludge, digestion, no two of the same type are identical. Every engineer has his own ideas for every step in the process, some being good while others have proved to be expensive failures. Although the author recognizes that sewage-treatment plants as a whole cannot be standardized, it should be possible at least to establish more or less uniform principles as to the mechanical appliances. As matters now stand each designing engineer bases his design on his own ideas and on whatever data he may have available. Therefore, anything done to bring about uniformity will give an added guarantee of satisfaction to those who eventually pay the taxes to finance the work. Failures contribute much to the views of some persons who steadfastly refuse to vote the necessary funds for relieving unsanitary conditions.



200-TON MODERN INCINERATOR IN PHILADELPHIA, PA., PLANT

The sanitary field is large. New York City alone, for example, is confronted with expenditures of well over one hundred million dollars for the construction of sewage-treatment plants and many millions more for garbage and rubbish incinerator plants. As a rule a sewage-treatment plant for an inland city represents an investment of $10 or more per capita. Sewage plants for seaboard cities are usually less costly as high-degree purification may be avoided in many cases. But even though only partial treatment is obtained the costs are great, and anything that the mechanical engineer can do to effect economies in construction and operating costs will undoubtedly result in opening up work which is now held up because of these enormous costs. Mechanical progress in the art during the past five years substantiates this statement.

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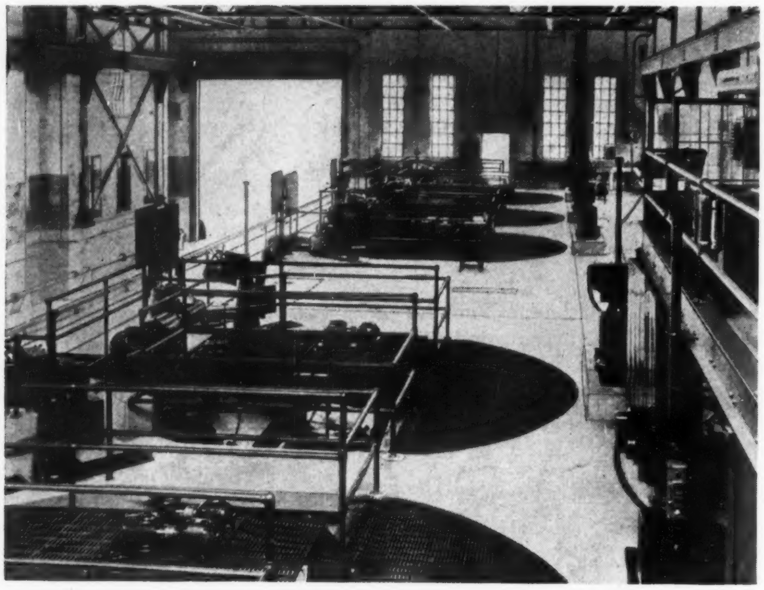
Contributed by the Process Industries Committee for presentation at the Semi-Annual Meeting, Chicago, Ill., June 25 to July 1, 1933, of The American Society of Mechanical Engineers. Slightly abridged.



REVOLVING FINE SCREENS OF DISK TYPE AT SOUTH YONKERS SEWAGE TREATMENT PLANT IN WESTCHESTER COUNTY, N. Y.

I—SEWAGE TREATMENT AND DISPOSAL

The three fundamental processes involved in sewage treatment are clarification, oxidation, and sterilization.

CLARIFICATION

Clarification involves the removal of the solid matter contained in the sewage. The solids fall into three general classes: suspended, colloidal, and soluble. Each of these is subject to further division into organic and mineral matter. The relative amounts of these six varieties of solids change daily, so that each plant must be designed to treat the sewage of a particular community. The changes in relative amounts of solid content may be attributed to various factors, such as the condition of the collecting sewers and the character of the sewage, whether domestic or factory wastes, storm water, or a combination of any or all. Some cities have attempted to regulate or restrict industrial wastes in order to protect the operation of their sewage plants, but this seems to be a short-sighted policy. The reason for such restrictions can be traced directly to the sensitiveness of biological treatment plants. It is not hard to realize that plants which depend upon the delicate action of bacteria are subject to serious upsets when acids are carried in the sewage. If mechanical and chemical means were to be used for clarification, the results accomplished would remain practically the same, day after day, and no restrictions on industrial wastes would be necessary. Hence, a filter for sewage should have the following characteristics: It should be capable of a high rate of filtration per square foot per minute, and a reasonable continuity of operation; it should be self-cleaning, or as nearly so as possible; it should use easily renewable and cheap filtering materials; its construction and operating costs should be low; it should be compact and have a flexible rate of filtration; and it should be adaptable to chemical conditioning when necessary. The combination of these features in a mechanical filter will offer positive clarification of any sewage. Experimental work during the past two years has demonstrated conclusively that such a unit is possible and that the final results will be far superior to those produced by settling or sedimentation tanks. Detailed analysis of the results of work along these lines as produced on a large scale will be available within the year.

Screens. Various types of fine screens have been employed for clarification purposes but even the best units cannot do more than remove the relatively large particles of solid matter. A screen with perforations as small as practical, $^1/_{64}$ in., cannot remove more than 40 per cent of the suspended solids and has no effect on the colloids and solubles. Attempts have been made to build up a secondary filtering medium on the plates of a fine screen by allowing the solids collected in the usual way to lie on top of the plate, thus forming a compact mat in which the smaller solids will be caught. While this is entirely practical and has increased the efficiency of removal, it still falls short of the goal. However, an efficient fine screen is ideally suited as a treatment preliminary to some other more complete clarifying unit.

Settling Tanks. Settling tanks are sometimes called clarifiers but only about 55 per cent of the suspended solids will be removed in them without the aid of chemicals or some other means to aid sedimentation. Many new treatment processes have been introduced during the past two years in order to improve these results. Generally they include one or more chemicals, such as lime, alum, chlorine, ferric chloride, or ferrous sulphate as a precipitant or coagulant. While these increase the efficiency, the process still falls short of complete clarification: The velocity of flow through the tank is the critical factor; a slight disturbance in the tank will stir up the solids which are settling or have settled, causing solids to be carried over the effluent weir; and if the usual oxidizing methods form the second step in the treatment, only a very light dose of chemicals can be applied without destroying the bacteriological oxidizing action.

Centrifugals. Centrifugals have also been considered for the clarification process. Experimental units have been built and tested but results from actual service are not yet available. If clarification can be accomplished by high-speed centrifuges at low operating costs, it is a step in the right direction. The greatest difficulty with centrifugals seems to be that they cannot continuously unload the solids which collect within the unit. While this is not absolutely essential in dewatering industrial and even sewage sludges, it is important if the machine is to be used as a sewage clarifier because of the tremendous quantity which must be handled. Sewage contains hair, twigs, leaves, match sticks, cotton fiber, and the like, making it almost impossible to keep the machine clear, because these particles are forced partly through the openings and tangle so that within a short time a solid wad or mat is formed. Even though the sewage is passed through a very efficient screen, some of this material will find its way into the centrifugal unit. Some centrifugals with solid bowls have recently been introduced but these are still in the experimental stages and, to the author's knowledge, none has been used in large-scale or permanent installations. In sewage treatment, slow speeds appear to be more satisfactory than high speeds because many of the suspended solids which could otherwise be removed with relative ease are converted by centrifugal force into colloidal matter which can only be removed by heavy chemical doses.

OXIDATION

Aeration. The purpose of the oxidation process is to intro-

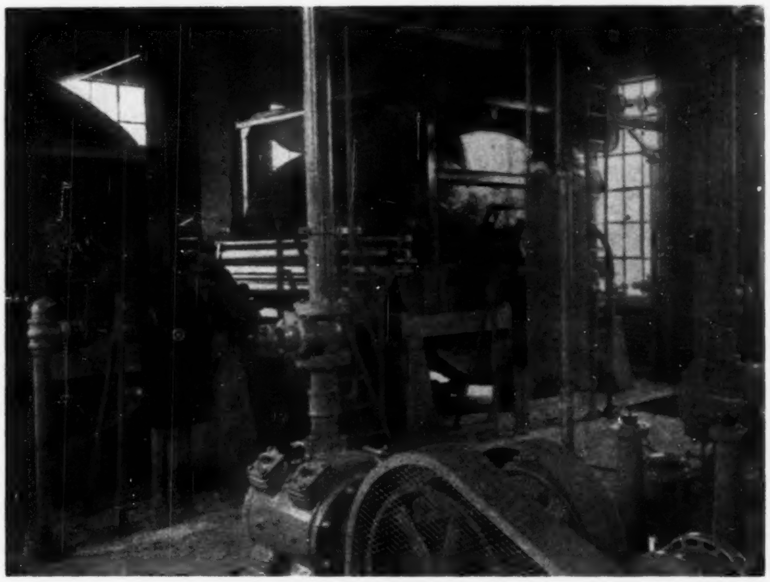
duce the required oxygen to the sewage as efficiently as possible. In the older processes, the sewage was pumped to a sufficient height to allow it to flow or sprinkle on stone or sand beds of four to ten feet in thickness. During the passage of the sewage through these beds it absorbed the oxygen required for stabilization. In the activated-sludge process the sewage flows through large tanks with a retention of about six hours, during which time air is continually pumped into the tanks at a pressure of approximately 7 lb per sq in.

Oxidation takes place through the medium of aerobic bacteria which multiply in the presence of oxygen. The volume of air required for complete activation is great, varying as a rule from $^3/_4$ to $1^1/_2$ cu ft per gallon of sewage treated. Inasmuch as sewage plants may be designed to treat more than two hundred million gallons a day, it is easy to realize that the problem of pumping air is tremendous.

Some oxidation methods combine mechanical agitation with the usual diffusion of pumped air. Judging from reports made public it would appear that mechanical agitation requires less power than the pumping of air, although much can be said in favor of each method. A thorough study of this phase alone would undoubtedly prove of immense value and result in great savings in operating costs. Many data are available which, if properly correlated, would form a basis for determining the path of greatest efficiency, not only in actual operating cost but in construction cost and reliability of operation. Following the period of aeration it is necessary to direct the sewage to secondary settling tanks where it is retained for about two hours, allowing the solids to deposit on the bottom and the clear liquid to run off at the top. If aeration has been incomplete, the solids will not be in a flocculant state and therefore will not settle. In this case, the effluent discharged from the plant will contain a relatively large quantity of solids which quickly destroy the stability of the liquid and defeat the purpose of the plant. The solids which settle must be quickly and continuously removed from the settling tanks to prevent septic action as this also seriously affects the efficiency of the plant. This is usually accomplished by revolving or drag scrapers which carry the sludge to a pit at the center or at one end, from which it may be discharged. The speed at which these scrapers move along the bottom of the tank is a critical factor as a slight excess will stir up the sludge or cause the solid particles to rise again to the surface.

Chemicals. Aside from the activated-sludge process, sprinkling filters, and other biological methods, oxidation may also be accomplished by chemicals. Lime, chlorine, and ferric chloride, or a combination of any or all, are the chemicals most commonly used. These may not achieve as high a degree of treatment as that produced biologically, but they have the advantage of more consistent results. It appears that a combination of mechanical and chemical means of oxidation could be devised and that it would occupy much less ground area, since the necessity for long periods of retention would be eliminated. It would undoubtedly lower the construction cost and would minimize the possibility of odor.

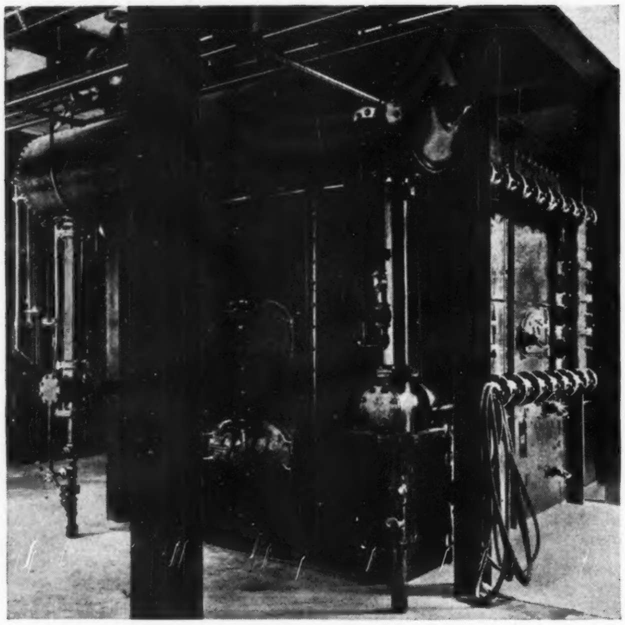
Chemical-Mechanical Process. In all present-day biological oxidation processes, the sewage first passes through settling tanks or fine screens where the best removal of solids that can be effected is approximately 50 per cent of the suspended matter. Unless chemicals are added, the colloids and solubles remain in the original quantity. However, as chemicals are generally injurious to biological oxidation, they are seldom used. It is therefore evident that under the present system about 50 per cent of the suspended solids, all colloidal solids, and all solubles are passed into the aeration tanks or stone filter beds for oxidation. If all the sewage could be thoroughly filtered or clarified before entering the aeration tanks, it is reasonable to expect that the load on the oxidation process would be greatly decreased, with a corresponding decrease in the cost of operation. Why oxidize so great a proportion of the solids when other methods can be employed to produce a stable sludge which can be promptly incinerated to avoid any possible nuisance? The liquid leaving the treatment plant is of prime importance and must, of course, be thoroughly oxidized. If the unnecessary load on the oxidation process can be eliminated, efforts can be concentrated on the production of better and more consistent results in the final effluent, at no greater cost. Whether this can be done with the usual activated-sludge process is doubtful, as a certain amount of solid matter is necessary to cultivate the required bacteria, and biological oxidation would hardly be possible under this condition so that some form of direct mechanical or chemical oxidation would have to be used. Judging from past performance it would appear that mechanical appliances with chemicals can and eventually will solve the problem.



VACUUM FILTERS FOR SEWAGE-SLUDGE TREATMENT, HAGERSTOWN, MD., PLANT

STERILIZATION

In the paragraphs devoted to oxidation no mention was made of its germ-killing powers. This applies to any oxidation process but none can be relied upon entirely for positive sterilization. Sterilization is more often accomplished by dosing the final effluent from the plant with chemicals, particularly chlorine. This method is economical and reliable and will probably remain in use for many years to come. The amount of chlorine can be accurately measured before dosing, and the residual present after the proper period of contact with clear liquid offers reasonable assurance that the work has been done. It sometimes happens that large particles of solid matter are not completely penetrated during the period of contact. If sewage is thoroughly clarified or filtered before chlorination, this is not likely to happen and less chlorine will



TWO 50-TON REFRACTORY-LINED FURNACES, HEMPSTEAD, L. I., PLANT

be required to complete the sterilization. It is advisable to incorporate some type of mechanical mixer at the point at which the chlorine is introduced to the sewage. At the present time this is accomplished only by a distributing manifold located at the bottom of the tank.

SLUDGE DISPOSAL

What has been said so far relates particularly to the removal of solid matter from the liquid and the preparation of the liquid for safe discharge into a watercourse. The problem of properly disposing of the extracted solids has, however, been sadly neglected in many plants. This phase is just as important as the treatment of the liquid. Very often sewage-treatment plants having no provision for sludge destruction or conversion are improperly called disposal plants. There are two general ways of disposing of this sludge. The first and most positive method is to dewater the sludge as much as possible, and then burn it. The second is to process and dehydrate the sludge so that it may be used as a fertilizer. The latter method depends, however, on an uncertain market for the sale of the product and on uncertain prices. Thus it may result in sacrificing the primary object of the plant in favor of the production of a salable product. Until quite recently many engineers considered incineration rather difficult but this was due to a lack of knowledge of inexpensive methods of dewatering sludge prior to incineration.

The sludge drawn from a settling tank usually contains from 95 to 99 per cent water. Unless the sludge is first concentrated, incineration is out of the question. The most popular method to accomplish this is the use of vacuum filters. A vacuum filter can reduce the moisture content to from 60 to 80 per cent, depending upon the process used to produce the sludge. For instance, a raw or fresh sludge can be dewatered to a greater extent than activated sludge. The method used in conditioning the sludge prior to filtration also has some bearing on the ultimate moisture content. Several methods may be employed for conditioning sludge, such as the addition of ferric chloride or ferrous sulphate, the addition of lime, the addition of shredded waste paper, or a combination of any of the above. The sludge is discharged from the vacuum filter in the form of a cake or continuous sheet which varies in thickness from $^1/_{16}$ to $^1/_2$ in., depending upon the nature of the sludge and the means of conditioning. This product may be dried even further although it is not necessary to do so in order to obtain efficient incineration. An undigested sludge has a calorific value of approximately 7500 Btu on the dry basis, or about 2500 Btu per lb of sludge cake, if the moisture content is assumed to be $66^2/_3$ per cent. It is evident from these figures that self-sustained combustion is theoretically possible. However, in burning sewage sludge a minimum temperature of 1400 F should be maintained to eliminate the possibility of odor and therefore auxiliary fuel, such as coal, oil, or gas, is used. If a sewage-treatment plant and a garbage and rubbish incinerator plant were located adjacent to each other, much of this auxiliary fuel could be saved, as rubbish would make up the deficiency at no increase in cost. This is of course contingent upon proper incinerator design, and some special features would be required. An incinerator designed for the destruction of garbage and rubbish would not necessarily be in a position properly to accommodate sludge cake. Very few installations offering complete destruction are now in operation. The thought is still new to the majority, but present indications point to a time in the near future when all sewage plants will be equipped with this facility.

In a method of sludge disposal frequently used in the past the sludge with a high moisture content is drawn from the settling tanks and placed in digestion tanks where it remains from one to six months. After it has been thoroughly digested it may be deposited on drying beds where it remains from two to eight weeks. When the moisture content has been reduced to 60 per cent or less, the sludge can be removed and used as dry fill. It has been demonstrated that a mechanical vacuum filter can dewater this digested sludge within a few minutes and produce a cake comparable to that obtained after weeks of drying on sand beds.

Another method of sludge disposal sometimes used is that of dumping at sea. It is unsanitary, to say the least, and defeats the prime purpose of the treatment plant. While dumping is supposed to take place from 15 to 25 miles from shore, the actual distance depends entirely upon the human element.

MECHANICAL APPARATUS IN USE

There is much room for standardization and improvement in the appliances incidental to the major apparatus of sewage-disposal plants. This includes such items as pumps, blowers, compressors, meters, gages, gates, conveyors, elevators, screens, cranes, furnaces, driers, shredders, agitators, and the like. If these auxiliaries do not function properly the entire process may be upset. Sewage cannot be stored for any length of time, first, because the volume is enormous, and second, because it becomes septic very quickly, resulting in an odor nuisance. All auxiliary apparatus must be designed especially for sewage work. Apparatus used in waterworks is not as a rule suitable for sewage, because of the uncertain nature and quantity of solid matter which it includes.

Centrifugal pumps must be equipped with special impellers having large clearances. The pumps, and any other apparatus that comes in contact with sewage or sewage gases, must be made of materials that will withstand erosive and corrosive action. In designing pumps on non-clogging principles the efficiency is lowered considerably. Slow speeds are preferable in sewage work for the reason that solids should not be broken down any more than is absolutely necessary. Any efforts to bring about some degree of uniformity in sewage-pumping apparatus should result in better and more efficient operation of

the plant as a whole. It is also within the bounds of possibility to revise present-day methods of treatment so that the pump can be returned to its normal function of lifting relatively clear liquids. There are exceptions, of course, but in all instances at least the major solids can be removed before the liquid enters the pump.

Meters for sewage are also affected by the solids which accumulate at the throats or in the openings to the pressure chambers. Venturi meters are sometimes provided with plungers which may be worked manually to keep the openings clear. In others a reverse flow of clear water is used for the same purpose. Wherever possible, sewage should be clarified before metering, but many times this is not possible. For this reason it appears that further development is necessary to produce a meter that is not affected by particles of solid matter. Even an ordinary weir is subject to serious error when sewage solids are present. Materials such as rags, twigs, leaves, and the like, form obstructions requiring inspection at regular intervals.

Much might be said regarding the other auxiliaries in sewage treatment but space will not permit the consideration each deserves. Each item requires special features and materials to make it suitable for use in this field.

II—GARBAGE AND REFUSE DISPOSAL

As in sewage treatment, so in garbage and rubbish disposal, special means must be employed to insure successful and economical operation. In contrast to sewage practice, however, almost all of the development work in garbage and refuse disposal has been done by the manufacturers of incinerators and reduction equipment. In justice to the incinerator manufacturers, it should be said that the leading companies have developed incineration to a high degree of efficiency and are not deserving of the criticism charged against them in the early days of experimentation.

BURNING ON OPEN DUMP

Many methods of garbage and rubbish disposal have been tried and many are in use today but by far the greatest number of communities still use the open dump with its obnoxious smoke and odor which cause depreciation of property values. Only present economic conditions permit the continuance of this practice.

HOG FEEDING

In New England, California, and several mid-western sections the prevailing method of garbage disposal is hog feeding. In some instances hog farms are owned and operated by the municipality, but in most cases contracts are entered into with private companies for the collection of garbage and its subsequent use as feed. The unsanitary conditions brought about by this practice are causing the method to lose favor and it is only a question of time before it is done away with entirely.

DUMPING AT SEA

Dumping garbage at sea is another method which is being discouraged. The recent injunction by the Supreme Court of the United States against the City of New York which prohibits the practice after June 1, 1933, is an example.

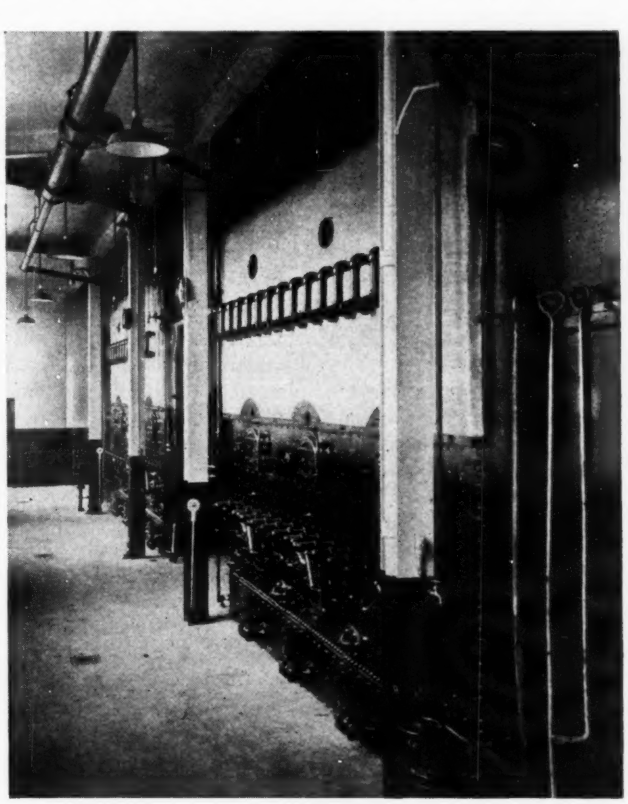
REDUCTION PLANTS

The process of reduction has had a certain degree of success, reaching its most profitable peak during and immediately after the war. This method involves the reduction of garbage to grease and tankage and its success depends entirely upon the prices that these products command. Because of the heavy cost of installation, reduction has been almost consistently confined to cities with populations above 100,000. Because of uncontrollable odors given off during reduction, the plants are usually located on isolated sites. This makes longer and more expensive hauls necessary. Furthermore, a separate collection of rubbish is necessary and some other means must be provided to dispose of it. The latest reduction plant in this country was built in Schenectady, N. Y., in 1925, and since that time many have been abandoned or replaced by incinerators.

INCINERATOR PLANTS

During the last ten years more than 300 municipalities have purchased incinerator plants. This indicates a trend toward cleaner and more sanitary conditions.

The brick type of incinerator was originated in England but has been carried to its greatest efficiency by developments made by manufacturers in this country. Brick furnaces are built in various shapes; some are rectangular while others are square or round. The capacity of a furnace unit usually ranges from a few tons to 150 tons of refuse per 24 hr. The small units consist of one cell while those of 50 tons or more are generally made up of multiple cells. Inclined brick or metal drying hearths are installed at the sides or back of the combustion grates. Each cell is provided with a charging hole in the top so that fires can be maintained in adjacent cells while any one of them is being cleaned without materially lowering the temperature of the furnace. The furnaces are rated on the basis of the pounds of refuse burned per square foot of grate surface per hour but the ratings vary according to the ideas and experience of each particular manufacturer. Unless the purchaser specifies the grate surface desired, it is probable that



TWO 100-TON STEEL WATER-JACKETED FURNACES, PHILADELPHIA, PA., PLANT

a wide range of sizes will be offered, because some manufacturers include a portion of the drying hearth in their calculations for grate surface.

One type of furnace which has received considerable recognition is circular in plan and is provided with an arched roof containing a charging hole in the center. The purpose of this construction is to permit the formation of a cone of material at the center of the furnace. Another recent development is a rectangular brick furnace containing suspended water-cooled grates.

The steel water-jacketed incinerator is constructed along the lines of a steel firebox boiler. It is usually equipped with special dumping grates that provide large clearances and in addition it contains a water-cooled basket grate which is suspended directly over the dumping grates. As the refuse is dumped through the charging hole at the top of the furnace it falls into the basket grate where pre-drying and a certain amount of combustion takes place, after which it falls or is stoked on to the lower grate. This arrangement permits two fires, one above the other, in the one firebox. The units are built in sizes of from 20 to 150 tons of refuse per 24 hr. Ratings are established on the basis of cast-iron grate area and as a rule one square foot of cast-iron grate surface is provided for about 80 pounds of mixed refuse to be burned per hour. Generally speaking, one pound of steam is produced with each pound of refuse at normal mixture, and this is sufficient not only to operate all steam-driven auxiliaries but to heat the buildings and generate enough electric power to operate cranes and furnish lighting.

Incinerator plants may be constructed of almost any size. Separation of garbage and rubbish is not necessary as an incinerator can handle the combined material. It is, in fact, desirable to mix the material, as straight garbage cannot be burned without additional fuel. Garbage generally contains 70 per cent moisture and in that state its heating value is approximately 2500 Btu per lb. Rubbish on the other hand is relatively dry and contains approximately 7000 Btu per lb. Ordinarily a normal mixed collection will yield about one part of rubbish for every two parts of garbage by weight and this proportion allows not only proper high-temperature incineration but also the preheating of air and the generation of steam.

ESSENTIAL FEATURES OF INCINERATOR PLANTS

In designing an incinerator the essential features that must be provided are: large furnace volume, sufficient combustion-chamber volume, effective drying hearths, large charging openings, dumping grates, large ashpits, stoking doors on as many sides as possible, and chimneys of sufficient height. It may also be advisable to include air preheaters, not only from the standpoint of economy but to lessen the possibility of the escape of unburned gases which might constitute a nuisance. Sometimes it is advisable to introduce baffles or checker walls to knock down dust particles, but this result can also be accomplished by providing for slow velocities, turns, and pits in the combustion chamber and flues. A minimum temperature of 1250 F with an average of 1400 F should be maintained in the combustion chamber to insure odorless operation. This is too often overlooked by incinerator designers or is sacrificed to lower the construction cost in order to meet competition.

Maintenance costs and efficiency should be primary considerations in selecting an incinerator plant rather than first cost alone. The furnace of one manufacturer may have a useful life of 25 years while that of another may be limited to 10 years or less. One furnace may be constructed with an ordinary firebrick lining, another of carborundum brick, and still another with water-cooled steel jackets. It is obvious that the lengths of life of these materials differ widely, although until now little has been done to evaluate the difference. In all except one or two instances incinerators require electrically driven auxiliaries such as blowers and compressors which add to the operating costs. The steel water-jacketed unit not only eliminates the regular furnace-lining repairs but generates steam as well.

In garbage and rubbish incineration there is always an uncertainty of fuel value. This prevents the design of a furnace for known fuel quantities and values as in steam-power practice. The proportion of garbage to rubbish as well as the size of the load to be disposed of may change hourly. Considering the fact that the volume changes with the proportion of garbage to rubbish, and that rubbish weighs on an average of 200 lb per cu yd against 1100 lb for garbage, it is evident that incinerator manufacturers must not only provide an ample factor of safety but must be thoroughly familiar with the peculiar conditions of each section of the country in so far as waste production is concerned.

It is customary to supply air preheaters with all high-grade furnaces. These preheaters are of the stationary type and may be constructed of iron, steel, or tile. The amount of surface provided is usually sufficient to raise the combustion-air temperature to approximately 400 F, which actual practice has shown to be both practical and economical. Preheaters with relatively small openings are not used as a rule on account of the presence of large quantities of dust, and the expense of providing a special metal which will withstand the corrosive action of the gases and vapors as well as intermittent heating to high temperatures. Considering the fact that more than one-half the weight of garbage is water which is driven off by evaporation in the form of a highly superheated steam, it is evident that the vapor thus produced constitutes a far more difficult problem than that ordinarily encountered in steam-power-plant practice. Steel stacks are seldom used with incinerators for the same reason. The usual radial-brick chimney with full lining seems to be best suited to meet these requirements.

Few mechanical engineers appreciate the fact that a modern incinerator with its heaters, air-cooled walls, insulation, steel casings, blowers, dust collectors, and other auxiliaries is comparable in many respects to a steam power plant. Accuracy of design is even more important as an error may result in the setting up of an odor nuisance which in turn may bring about legal action to prohibit further operation.

CONCLUSION

This paper has dealt with the problem of municipal sanitation in its broadest sense and of necessity has omitted many incidental, but important, features. Each step or phase of sewage treatment and refuse incineration warrants individual consideration and might form the basis for separate papers and discussions. This paper is offered with the hope that it will arouse the interest of all mechanical engineers so that they will cooperate with sanitary engineers in the development of new and more practical methods and apparatus for use in this field. Anything that will unify the independent practices of today will not only materially benefit the profession but will also save the taxpayers of hundreds of communities many millions of dollars. While many engineers will say that standardization in this art is impossible on account of the great variety of local conditions, the fact remains that it is possible to standardize at least the component parts which go to make up the system.

High-Boiling-Point ORGANIC COMPOUNDS

By J. J. GREBE[1] and E. F. HOLSER[2]

Economic conditions in the past ten years, with their demands for increased efficiency in industrial processes, have provided a tremendous impetus for the development of industrial heat-exchange systems. It is the object of this paper to summarize the recent developments in the field of industrial heat exchange, particularly as related to heat-transfer fluids; to disclose certain new compounds which are suitable for use as heat-transfer mediums at high temperatures; and to suggest some possible new uses for these compounds.

Water has always been the accepted fluid medium for transferring heat. Oils have been used as heat-transfer mediums at temperatures up to 550 F, and mercury was introduced by the General Electric Company as a fluid medium in power-generation cycles. The latter material has also been used in many industrial heat-exchange applications, the most important of which are those of the Sun Oil Company. However, no one fluid has been found which can answer all the requirements of each installation. Therefore, investigators began a study of other substances which might be utilized, particularly stable organic chemical compounds having high boiling points, which would be an improvement over the oils.

The most promising compounds found were pyrene, phenanthrene, diphenylene oxide, diphenyloxide, diphenyl, toluol, and benzol. The last two were found to have boiling points that were too low, and the others were too expensive. The problem then was to find a means of making the desirable compounds available in commercial quantities at reasonable prices.

About 1922 The Dow Chemical Company developed a new commercial method for the production of phenol and diphenyloxide (6).[3] Before that time diphenyloxide was a laboratory product and very expensive. It was found that this compound was exceedingly stable when heated. In fact, its stability was such that it was proposed to use it as a heating medium around the reactor in which it was produced.

In 1925 Dr. Herbert H. Dow instigated research work on the thermal properties of diphenyloxide, the results of which were presented before the Associated Technical Societies at Detroit in February, 1926. This paper was elaborated and later presented at an A.S.M.E. meeting at Cleveland in June, 1926, giving temperature-entropy diagrams and suggested power cycles (1–5). This paper pointed out that the compound was available at a reasonable cost of 30 cents per pound in 1926 (18 cents per pound, in quantities, in 1933).

A small boiler representing one tube of a large boiler with natural circulation was tried out and operated under various conditions during the spring and summer of 1926 (Fig. 1).

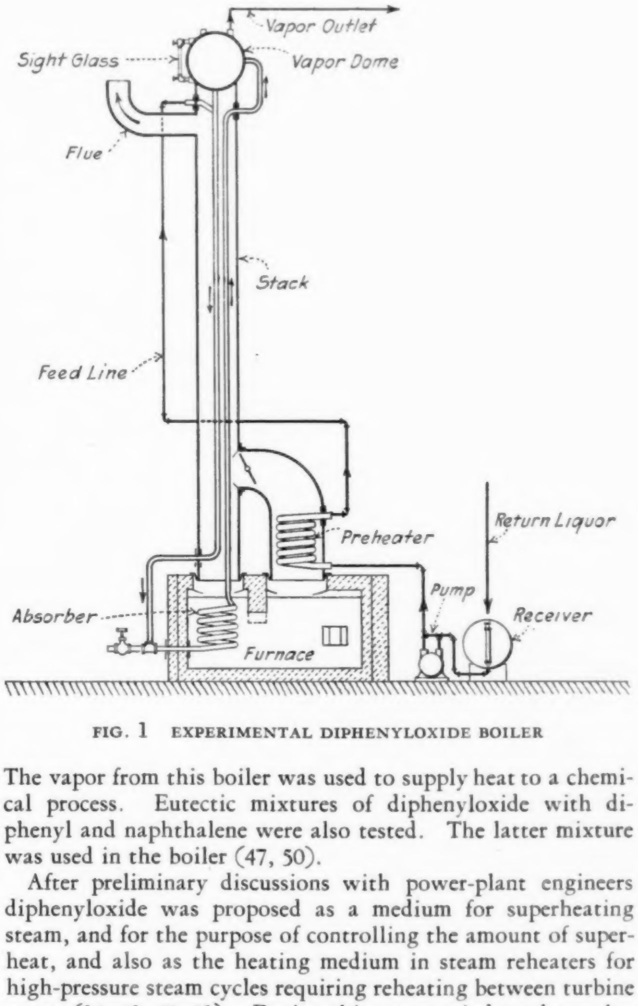


FIG. 1 EXPERIMENTAL DIPHENYLOXIDE BOILER

The vapor from this boiler was used to supply heat to a chemical process. Eutectic mixtures of diphenyloxide with diphenyl and naphthalene were also tested. The latter mixture was used in the boiler (47, 50).

After preliminary discussions with power-plant engineers diphenyloxide was proposed as a medium for superheating steam, and for the purpose of controlling the amount of superheat, and also as the heating medium in steam reheaters for high-pressure steam cycles requiring reheating between turbine stages (14, 48, 49, 51). During this same period work was being done in Europe by J. K. Ruths, following up his early work on heat storage by the use of phenanthrene (26, 27, 40, 41, 43).

We next find the oil industry interested in high-temperature heat-transfer mediums and the development, in 1927, of the Govers' distillation process for lubricating oils in which accurate temperature control by indirect heat at temperatures around 700 F was the main feature (11, 12, 45). Diphenyl was the compound selected for this purpose. This material was made commercially available by the Federal Phosphorus Company (7, 9, 16, 17).

These applications, and others suggested, stimulated an active interest in high-boiling-point organic chemical compounds and various colleges and technical schools were working on the problem of accurately determining the various physical constants for some of the more promising compounds (22). Notable among these are the work of Chipman and Peltier (8), of

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[3] Figures in parentheses refer to items in bibliography at the end of this article.

Contributed by the Power Division for presentation at the Semi-Annual Meeting, Chicago, Ill., June 25 to July 1, 1933, of The American Society of Mechanical Engineers.

the Georgia School of Technology, in 1929, and that of Forrest, Brugman, and Cummings (20), of the Massachusetts Institute of Technology, and Newton, Kaura, and DeVries (19), of Purdue University, in 1930.

In 1930 the first large-scale commercial application of a high-boiling-point organic chemical compound as a heat-transfer medium for air preheating was made at the Bremo Station of the Virginia Public Service Co. under the direction of R. C. Roe (18, 21, 23, 24, 25, 29, 30, 33, 34, 36). At this time also there was an investigation made by Badger, Monrad, and Diamond, of the University of Michigan, in which they studied the evaporation of caustic soda to high concentration by means of diphenyl vapors (10, 15, 28, 53), and later the study made by McCabe, of the same university, of the heating of asphalt (37), with a similar set-up made in 1930 and 1931.

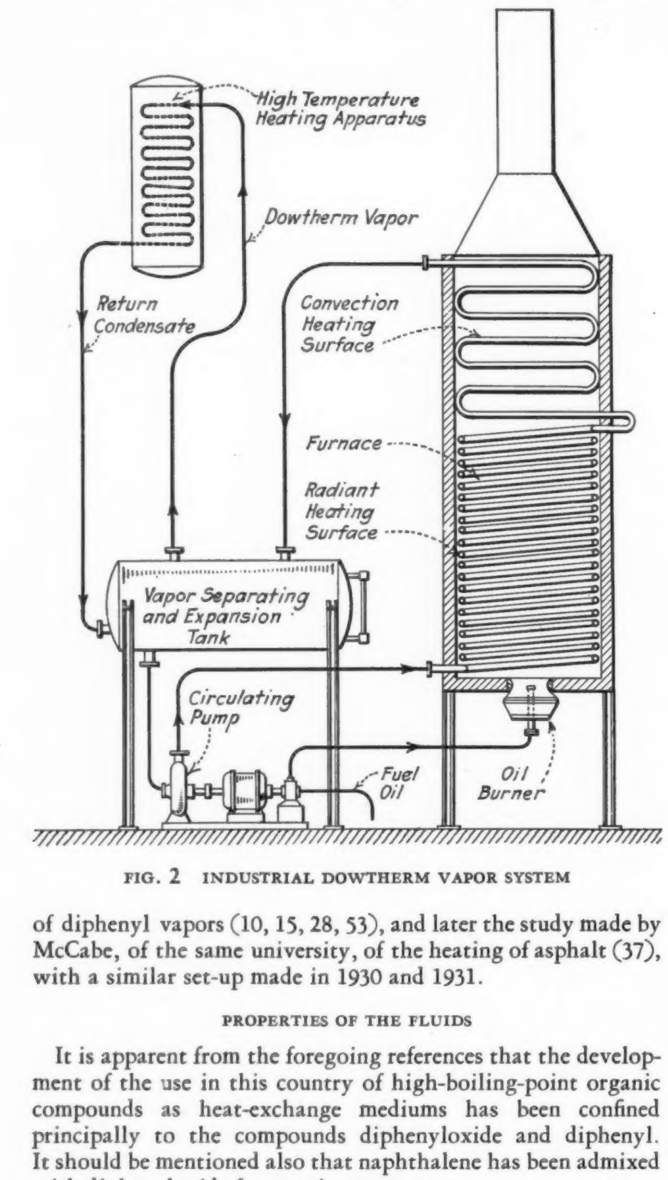

FIG. 2 INDUSTRIAL DOWTHERM VAPOR SYSTEM

PROPERTIES OF THE FLUIDS

It is apparent from the foregoing references that the development of the use in this country of high-boiling-point organic compounds as heat-exchange mediums has been confined principally to the compounds diphenyloxide and diphenyl. It should be mentioned also that naphthalene has been admixed with diphenyloxide for certain purposes.

Diphenyloxide has the chemical formula $(C_6H_5)_2O$ and is a colorless crystalline solid with a melting point of 80.6 F and a boiling point of 496 F at atmospheric pressure. Diphenyl has the chemical formula $(C_6H_5)_2$, and is also a crystalline solid with a melting point of 156.6 F and a boiling point of 491.5 F. Both these compounds have the disadvantage of freezing or solidifying at temperatures above that of the ordinary room. The eutectic mixture of the two has a melting point of 56 F, and is now marketed under the trade name Dowtherm "A." It has the approximate proportions of 75 per cent diphenyloxide and 25 per cent diphenyl.

Another suitable agent for reducing the melting point of diphenyloxide is naphthalene. The eutectic mixture consisting of 85 per cent diphenyloxide and 15 per cent naphthalene melts at 62.6 F and is designated as Dowtherm "B." It has a lower boiling point than Dowtherm "A" and for this reason is not quite so widely applicable to heat-transfer problems as Dowtherm "A."

An important feature of all the organic compounds suitable for heat-exchange work is that the liquids and their vapors are not toxic in character. In all of the authors' experience no poisoning has ever occurred with these materials, and it is not necessary to take special precautions against poisoning when working with them. Their effect on the skin, provided they are not hot enough to burn, is about like common kerosene. They have characteristic odors, in general not disagreeable, but which serve a useful purpose in making easy the detection of the slightest leak.

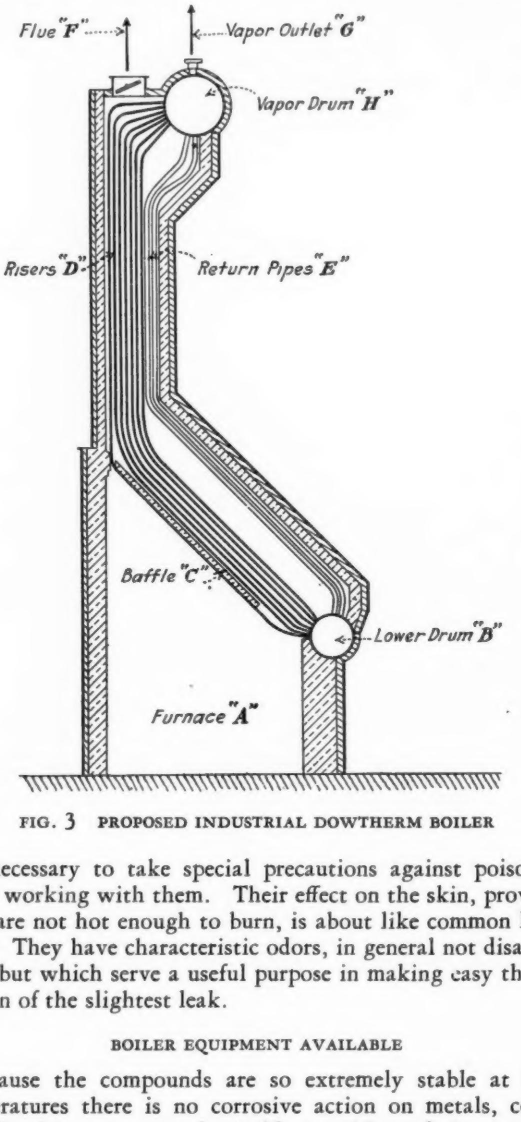

FIG. 3 PROPOSED INDUSTRIAL DOWTHERM BOILER

BOILER EQUIPMENT AVAILABLE

Because the compounds are so extremely stable at high temperatures there is no corrosive action on metals, consequently almost any metal suitable to withstand the temperature to be encountered with them may be used. Since their upper temperature limit is about 750 F, it follows that ordinary carbon steel is the cheapest and most satisfactory metal for the construction of heat-exchange apparatus.

Several boiler manufacturers have designed and built boilers for use with these organic heat-exchange compounds. (See Figs. 2 and 3.) They have also had considerable experience in the selection and furnishing of suitable accessories, fittings,

PHYSICAL CHARACTERISTICS OF HIGH-BOILING-POINT ORGANIC COMPOUNDS

	Composition	Melting point, deg F	Solidifying temp., deg F	Flash point, deg F	Boiling point or range, deg F	Recommended maximum deg F	Sp gr, room temp.	Sp ht range	Viscosity, millipoises	Applications for heat storage and heat transfer
(1) Diphenyloxide.....	$(C_6H_5)_2O$	80.6	80.6	230	496	750	1.08	0.4–0.6	30 at 100, 3.7 at 500	Power plants, chemical processes
(2) Diphenyl..........	$(C_6H_5)_2$	156.6	156.6 pure	200	491	750	1.16	0.4–0.6	......	Power plants, chemical processes, oil distillation
(3) Naphthalene.......	$C_{10}H_8$	176	176	187	424 subl.	800	....	......	......	Sublimes
(4) Dowtherm "A"...	74% (No. 1) 26% (No. 2)	56	56–40	215	495	750	1.1	0.4–0.6	30 at 100, 3.7 at 500	Power plants, chemical processes
(5) Dowtherm "B"....	85% (No. 1) 15% (No. 3)	62.6	62.6–50	200	485	750	1.1	0.4–0.6	42 at 100, 3.7 at 500	Power plants, chemical processes
(6) Dowtherm "C"....	No. 1 polymerized, No. 2 polymerized, and other benzene polymers	70–270	50–170	350	600–800	800	1.1–1.2	0.35–0.65	Very fluid at 300	Power plants, process industry, laboratories, cylinder-head cooling
(7) Dowtherm "D"...	Desirable compositions not completely determined	Softens at various temperatures[a]	None	None	600–800	600	1.4–1.6	0.25–0.45	Very fluid at 200	Process industries, laboratory baths, home machine unit, transformer fluid, lubricant

[a] Depending on composition.

valves, etc., for use with these materials. Heat-exchange apparatus, such as air heaters, heating coils, stills, jacketed kettles, shell and tube heat exchangers, jacketed pipe, etc., will in general follow present practice and can be furnished by any reputable manufacturer of such equipment, provided it is designed to withstand the high temperatures to be encountered.

In general the handling of these vapors and liquids in pipes and vessels involves somewhat more care in construction to insure initial tightness and continued freedom from leaks than would be required for the corresponding pressures with steam or water. This is because of the lower surface tension and viscosities of the materials at high temperatures. For these reasons welded construction is superior to riveted and is recommended wherever possible. Rolling of tubes into headers or tube sheets is satisfactory, provided expansion is properly cared for, and scale, rust, and other foreign material is carefully removed from tube ends and headers before rolling.

All places requiring packing, such as stuffing boxes on pump shafts, valve stems, etc., should be made deep and only the best grades of high-temperature packing used. Piping construction should follow the best high-temperature practice. Screwed joints are satisfactory for small sizes, but care should be taken to see that perfectly cut threads are secured. Flanged joints having the flanges welded to the pipes and using soft metal gaskets are found to be satisfactory.

Safety and relief valves of good grade, equal to those used for oil-still service, should be used. It is desirable to have safety and relief valves set considerably above the normal working pressure so as to prevent loss of material, and arrangements for condensing and saving the discharge from safety valves is recommended.

For liquid-level gages, a flat type using a mica window instead of glass has been found to give excellent results.

In testing out piping systems, heating vessels, or other apparatus which are to be used with these organic compounds, the ordinary method of applying cold water pressure is not effective. A better method is to introduce into them a small quantity of ammonia gas, and then apply air pressure. Leaks may then be detected by applying a lighted sulphur candle or dilute hydrochloric acid swab. If leaks are present a white fog will result. Apparatus which shows tight under this test can be depended upon to be tight in use with any of the compounds.

HEATING COSTS AND HEAT TRANSFER

The cost of heat generated for transfer with organic liquids or vapors will naturally vary greatly, dependent upon fuel cost, local conditions, and methods of operation. Since in many systems employing these agents the working temperature of the fluid will be about 700 F or above, it follows that stack gas temperatures necessarily must be relatively high. The fuel requirement is largely determined by the stack gas temperature of the boiler installation. However, where fuel cost and size of installation justify it, air preheaters can be used and stack gas brought down to low temperatures. Thermal efficiencies of 60 to 65 per cent may be expected where air preheating is not employed and 70 per cent or better when air preheating is used, depending of course upon the degree of preheat.

At the Midland Plant of The Dow Chemical Company an oil-fired Dowtherm boiler (13, 31, 32, 35) has been operated, without an air preheater, at rates varying from 2,000,000 to 4,500,000 Btu per hour, net heat output, at test efficiencies above 60 per cent at all points. The maximum manufacturer's rating of this unit was 4,000,000 Btu per hour.

Most of the organic chemical compounds used as heat-transfer mediums have a very low liquid viscosity, consequently circulation and agitation of the boiling liquid due to density changes can take place freely. This is in direct contrast to oils, where the relatively high viscosity hinders the free movement. Local overheating is apt to take place, resulting in decomposition with the attendant formation of carbon and obstruction of the normal heat transfer. It is well known that with lower viscosity the stationary film of liquid next to the metal surface in a tube will be thin and at a given velocity will have a lower resistance to heat flow.

In the case of condensing vapors much higher rates of heat transfer are usually encountered than with liquids. Condensing steam reasonably free from air or other non-condensables has a film coefficient reaching values of 2000 to 3000 Btu per sq ft per hr per deg F temperature difference between the

vapor and the tube wall. With liquids on the other side of the tube, the overall heat-transfer coefficient will usually be somewhere between 200 to 1000. The rate of heat transfer with condensing vapors other than steam is known to be much less, due principally to the fact that all other liquids have much lower thermal conductivities than water, and consequently the resistance of the condensate film is higher.

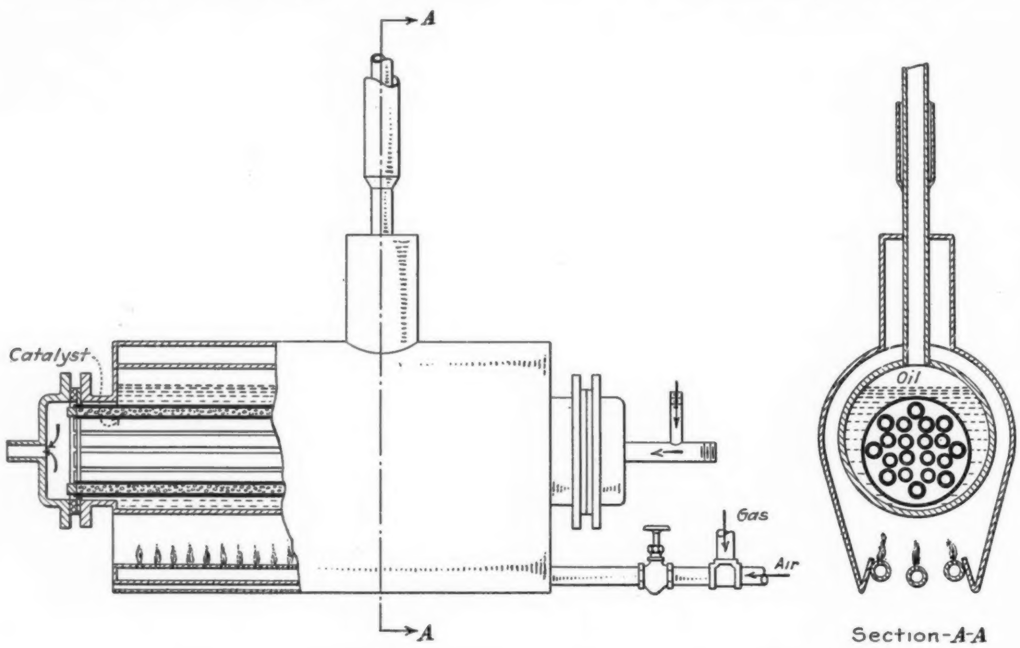

FIG. 4 CHEMICAL REACTOR USING DOWTHERM JACKET—750 F AND ATMOSPHERIC PRESSURE

The same comparison holds true between organic vapors and steam. It should be definitely understood, however, that while the film coefficient for these condensing vapors is much less than for steam, it nevertheless has a very satisfactory value, ranging from 150 to 500 Btu per sq ft per hr per deg F temperature difference between the vapor and tube wall, with about 300 Btu being an average value which can reasonably be expected in commercial practice. As to what the overall coefficient of heat transfer will be depends upon the kind of material on the other side of the dividing wall, its velocity, and other factors, which would influence the heat-transfer rate, irrespective of the heat-supplying medium.

NEW FLUID BOILS AT 750 F

It will be noted from the above characteristics that no one product is adapted to fill the demand for a universal high-temperature low-pressure medium. However, the interest of industry of a few years ago in these products has now reached a point of demand for either a universal product or a series of products with particular outstanding features for different applications. This attitude has been, and still is, responsible for continued research and the introduction of new products for specific classifications of heat-transfer work.

Within the last year a new Dowtherm product "C" has been developed which consists of a mixture of compounds similar to diphenyloxide and diphenyl, but containing more benzene rings to a molecule and having a considerably higher boiling point (38, 46). It is obtained by pyrolyzing these compounds. This product is a wax-like material at low temperatures and resembles an oil when liquefied at higher temperatures. It melts when slightly warmed and is capable of being heated to temperatures between 650 and 800 F without boiling. It is now available only in limited quantities, but has proved itself an excellent heat-transfer agent in a commercial operation where it was desired to maintain a temperature of 720 to 750 F without requiring pressure on the container. The flash point is above 350 F, so that the fire hazard would be considerably less than that with fuels which would be generally used to supply the heat. This material is being used very satisfactorily in a circulating liquid bath installation (Fig. 4), but it would not be recommended for vapor-phase heating. The low viscosity and high stability of this material point the way to the use of still higher temperature in standard industrial heat-transfer installations. These characteristics now make it possible to store larger quantities of heat in a given space at a higher temperature and without high pressure. The advantages of heat storage at a high temperature are very marked, since it permits not only the production of hot water and low-pressure steam, but also high-pressure superheated steam at temperatures up to, say, 750 F.

NON-INFLAMMABLE FLUID

Another Dowtherm product "D" for heat transfer has been developed very recently. It has the same advantages of high boiling point and high heat capacity per unit volume and is entirely free from fire hazard. This product offers, in the lower temperature ranges, advantages that have never been available before in that it can be used to absorb and transmit heat at temperatures up to 600 F without pressure, without fire hazard, without corrosion, and without obnoxious fumes or odors. At the present time laboratories are finding this new fluid an especially convenient material for high-temperature baths, thermostats, jacketed kettles, and other apparatus where a safe fluid must be used. Because of its fluidity it may be heated electrically or by direct flame. Its characteristics, however, limit its use to 600 F.

In common with the other fluids described it may be used for special purposes such as transformer fluids, and as an ingredient in lubricating oil (42, 44, 52).

This product also makes possible the application of modern engineering and thermodynamics to the mechanical equipment of a home in a complete and compact machinery unit. All the heat energy required in a home may be liberated and absorbed in a furnace filled with this heat-storage and heat-transfer fluid at a sufficiently high temperature to be available for practically all the processes requiring heat in the home. For example, the oven and hot plate of the stove can be incorporated into the heat absorber and be surrounded by the hot fluid at any temperature up to 600 F. A flash-type coil

water boiler, immersed in this fluid would convert water into superheated steam instantaneously without the necessity for any control or safety valve. The total quantity of high-pressure energy on hand at any one time would be negligible, and yet that steam would have a thousand uses in the home. Pressure cooking would be a pleasure. Heating small quantities of food would be very easy by direct contact or mixing with the steam. Superheated steam will roast and toast to perfection. There is no danger of scorching and burning. Air-conditioning and refrigeration equipment using heat as the source of energy may also be incorporated, so that a complete home machinery unit could be factory built and delivered on a single steel frame. All the mechanical equipment for the home, including the bathroom, kitchen, laundry, and heating fixtures, with much of the electrical equipment, could then be installed in the home by simply making water, sewer, gas or oil, and electric service connections to this machinery unit.

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A PREVIOUS investigation described the results of a study of the effect of tube length on heat transfer to water flowing in turbulent motion. It was concluded that for water in turbulent flow the effect of tube length on the rate of heat transfer is negligible. The present article describes the results of experiments on heating oil in both the viscous and turbulent regions using four lengths of 0.593-in. (inside diameter) copper tube. The oil used was a "light heat-transfer oil." The apparatus is described in the original article. The results are shown in the original article in the form of curves of $du\rho/\mu$ used as an abscissa, where d is tube diameter in feet, u the mean fluid velocity in ft per hr, and μ absolute viscosity of the fluid at the mean fluid temperature in lb per hr per ft, taken at a temperature equal to $(t_1 + t_2)/2$, t_1 and t_2 being inlet temperature and outlet temperature, respectively, and ρ the fluid density, lb per cu ft.

From the data adduced it would seem that in the viscous range the temperature rise decreases as the Reynolds number increases, but rises suddenly at the critical point and tends to flatten out in the turbulent region.—P. K. Sherwood, B. D. Keily, and G. E. Mangsen, Worcester Polytechnic Institute, Worcester, Mass., thesis for degree of B.Sc., 1931, abstracted through Trans., American Institute of Chemical Engineers, vol. 27 (1931), pp. 154–168, and discussion, pp. 168–170.

MECHANICAL ENGINEERING

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GEORGE A. STETSON, *Editor*

Broader Representation

LAST month there were added to the names of members of the A.S.M.E. Committee on Publications on our title page those of the newly appointed advisory members, E. L. Ohle, of St. Louis, Mo., E. B. Norris, of Blacksburg, Va., and A. J. Dickie, of San Francisco, Calif. Through these new representatives the Committee hopes to establish closer contacts with readers of MECHANICAL ENGINEERING in these places and their environs.

For a Wider Outlook

IN AN ADDRESS in commemoration of the 25th Anniversary of the opening of the Graduate School of Business Administration, Harvard University, Dean Wallace B. Donham, criticizing the over-specialization of the executives of our industrial corporations, said, "They have a fine understanding of their own companies, too little grasp of their industries as a whole, almost none of the relation between practical interests and our general social and economic structure, and far too little grip on the social consequences of their activities. . . . Business men do not undertake the hard intellectual job of securing a general grasp of these complex problems through prolonged exchange of varied viewpoints."

Many engineers are executives of industrial corporations; and the criticism is applicable to most engineers. MECHANICAL ENGINEERING has been striving to present a variety of points of view on the relationship of engineering to society. These discussions may not permanently settle many world problems, but they do give engineers something to think about; and it is hoped that they may serve to destroy some of the complacency of those who are willing to stand by an operable but inactive machine protesting that the technical aspects of the engineer's work are faultless. The engineer who feels that it is none of his concern if the world faces a difficult situation is likely to be accorded scant sympathy by that world.

A Hopeful Sign

FEW members of The American Society of Mechanical Engineers are fully aware of the success of the Committee on Relations with the Colleges in the recently inaugurated program of student membership. Last year the new plan was inaugurated in the branches of the southeastern states, and the first of the annual, regional, student-branch conferences that are part of the scheme was held at Chattanooga, Tenn.

Last fall the new plan was installed in three other regions. Four conferences have been held; the Southern Conference, at Birmingham, Ala., March 31 and April 1; the Eastern Conference, at Lehigh University, Bethlehem, Pa., April 21 and 22; the Midwest Conference, Chicago, Ill., April 28 and 29; and the New England Conference, Worcester Polytechnic Institute, Worcester, Mass., May 12 and 13. In addition there was held at the University of Washington, Seattle, Wash., March 30 to April 1, a Northwest Conference, although the new plan is not effective as yet in this region.

Comments by observers at these student conferences have been universally enthusiastic and commendatory. One feature worthy of emphasis is the excellent presentations of the technical papers by student members. The good work being done by departments of English and public speaking in our engineering schools was effectively demonstrated. Practicing engineers who read papers before technical societies could take lessons from these youngsters. It is to be hoped that this excellent performance is an indication that, as time goes on, the presentation of papers at meetings of engineering societies will improve. Perhaps the complaints so often heard that engineers are unable to express themselves in public are bearing fruit. It is a hopeful sign.

Industrial Trends in Wisconsin

A READING of the report on industrial trends in Wisconsin suggests that engineers might initiate and take part in investigations in other localities that would be directed to the same ends as was the one just completed in that state.

The report referred to, entitled "Industrial Trends in Wisconsin," was prepared by Edwin M. Fitch and Ruth L. Curtiss, of the Department of Economics, University of Wisconsin, for a supervisory committee consisting of Professors Harry Jerome and Martin Glaeser, of the University, and Mr. John P. Ferris, a member of The American Society of Mechanical Engineers who has frequently and conspicuously served his city, his state, and this Society.

The survey on which the report is based was undertaken "to determine the principal industrial advantages and disadvantages of Wisconsin towns and cities and to find out whether the large or smaller cities of the state have experienced the more rapid manufacturing growth." Briefly, the summary shows that there is no general tendency of industry to expand faster in the smaller cities of the state than in the larger cities; that neither group possesses preponderant advantages; that certain important industries have expanded more rapidly in the state than in Milwaukee; that in general the original location of plants has not been a matter of deliberate choice; and that "Wisconsin manufacturers place the

efficiency of their labor supply as their most important industrial advantage and the tax situation as their principal disadvantage."

Important as these and the more complete findings of the investigation may prove to be to the manufacturers of Wisconsin, the purpose of directing attention to them is to suggest that other states follow the example set by Wisconsin and undertake similar studies and that engineers take the initiative in connection with them. Plenty of source material is available in the report of Ex-President Hoover's Committee on Recent Social Trends.

A Century of Progress Exposition

EXPOSITIONS, or World's Fairs, have played their part in national progress in the past. The Centennial Exposition at Philadelphia, in 1876, impressed the stimulating effect of machinery and power upon a country painfully recovering from a devastating Civil War, and changing from a frontier and agricultural to an industrial development. In its wake came an expansion of engineering, as shown by the establishment of The American Society of Mechanical Engineers, a rise in the number and usefulness of trade and technical periodicals, and a spread of engineering education. The cottage industries were rapidly disappearing into the numerous factories springing up in centers where power-driven machinery and the American system of mass production were demonstrating their economic superiority. Undoubtedly the widespread interest aroused by the Exposition assisted in these significant developments.

Forty years ago, in a period of economic depression similar to that of the present day, Chicago was the scene of the World's Columbian Exposition. Electricity was the lusty infant industry that was on display, and alternating current was on trial. Of George Westinghouse's contribution to this Exposition, Henry G. Prout wrote: "It has been maintained with some plausibility that the most important outcome of the Centennial Exposition of 1876 was that the people of the United States there discovered bread. So it may be maintained, with even more plausibility, that the best result of the Columbian Exposition of 1893 was that it removed the last serious doubt of the usefulness to mankind of the polyphase alternating current. The conclusive demonstration at Niagara was yet to be made, but the World's Fair clinched the fact that it would be made, and so it marked an epoch in industrial history. Very few of those who looked at this machinery, who gazed with admiration at the great switchboard, so ingenious and complete, and who saw the beautiful lighting effects, could have realized that they were living in an historical moment, that they were looking at the beginnings of a revolution."

This month Chicago is host to the nation and to the world in A Century of Progress Exposition. It is said that it is to be less of an exposition of products and more of an exposition of processes. Modern merchandising and modern means of travel and communication have kept the average citizen fairly well informed on what the shops of the world have to sell. But the withdrawal of industry to the factory, the replacement of handicraft by machine production, and the amazing growth of science and its influences on the lives of every one have made it more than ever necessary to understand the fundamental bases of our modern life.

This, we take it, is the spirit back of A Century of Progress Exposition. The world needs to be reminded that progress has been made and that the broad path of progress is ready for its feet to tread. Because of it, youth should be inspired and faith in progress born anew in the disheartened. It should rank with its predecessors in usefulness to our national progress. Engineering Week at Chicago will provide an excellent opportunity to combine attendance at the A.S.M.E. Semi-Annual meeting with an inspection of the Exposition.

Von Miller Retires

NEWSPAPER dispatches from Munich announce the retirement from the directorship of the Deutsches Museum of Dr. Oskar von Miller, honorary member of The American Society of Mechanical Engineers. Dr. von Miller's retirement recalls to mind his distinguished contributions to engineering. He will be remembered as one of the pioneers in the development of the electric light and power industry, having designed the first alternating-current installation in Germany. But to the world at large his great and more significant contribution is the Deutsches Museum.

As all engineers know, the von Miller concept of a museum of science and industry is no dry-bone collection of obsolete antiques to be gazed at with pity for the generations that were forced to put up with such crudities. Von Miller built up a series of vital displays on a route, within the buildings, that is said to be nine miles long; exhibits that illustrate not only the historical development of science and engineering but also the underlying principle upon which the arts and technologies are based, with pictures, dioramas, models, and every conceivable device for explanation and illustration, and equipped, in many cases, with means so that the observer himself may actuate the operating mechanism.

Museums of science and industry have been late in starting in this country. The one in Chicago was made possible through the generosity of Julius Rosenwald. It occupies the reconstructed fine-arts building that was the pride of the World's Columbian Exposition. That in Philadelphia, with its splendid new building, is a fitting tribute to Benjamin Franklin for whom it is named. The New York museum, initiated and maintained during its formative period through the generosity of Henry R. Towne, former president and honorary member of The American Society of Mechanical Engineers, is making splendid progress in its leased quarters in the Daily News Building. All of these museums owe much to the vision and inspiration of von Miller.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

AERONAUTICS

Relation of Aeronautical Research to General Engineering

THE article outlines the history of aeronautical research with particular reference to heavier-than-air machines. Among other things it states that it was found that the mixing of lubricating oil with a fuel containing an anti-detonant resulted in a virtual destruction of the anti-knock properties.

In connection with the two-stroke cycle the author refers to the possibility of eliminating the carburetor altogether and injecting a measured quantity of fuel in the form of a spray directly into the combustion space after the exhaust valve has closed, thus side-stepping a serious disadvantage of the two-stroke cycle, namely, the difficulty created by unburned fuel following the exhaust gases out. He refers to the work of the Langley Field Laboratory of the N.A.C.A. and to experiments at the laboratories of Ricardo in England with the high-speed single-sleeve-valve gasoline engine. An aluminum cylinder working at 1.76 atm inlet pressure, 5500 rpm, and a compression ratio of 6.36 to 1, gave an output of 246 lb per sq in. brake mep, corresponding to 107 bhp per liter of piston displacement.

To obtain a better idea of the significance of these figures a rather highly rated aero engine in common use today gives an output corresponding to about 0.41 bhp per cu in., which is just a little less than one-quarter of the output of 107 bhp per liter. Allowing for the fact that in the one engine the power required to drive the supercharger is deducted from the total brake horsepower available, while in the experimental unit this power is not reckoned in, there still remains a very large difference. The dependability and life of the experimental bench unit have so far proved to be exceptionally good.

The following extract from the 1929 report of the British Aeronautical Research Committee may be of interest:

"To obtain the fullest advantage from supercharging at any altitude, it will be essential to do away with hot exhaust valves. The single-sleeve-valve engine appears to offer the only possible solution. On these grounds we think it is worth developing, as offering the greatest scope for advance in the production of the high-duty engine of low weight per horsepower. The success of the single-cylinder investigations warrants the early production of an experimental design of a complete engine."

As regards compression-ignition engines, it is stated that in England dopes have been tried for lowering the ignition temperature of fuel oils. A small addition of ethyl nitrate has been found to produce a considerable improvement in the rate of combustion in engines of the directed-spray type, though in engines in which the distribution of the fuel is dependent on air movement or turbulence, the effect is not so great. In England very great hopes are being entertained as to the possibilities of the two-stroke sleeve-valve type of compression-ignition engine. A single-cylinder bench unit of this description is said to be giving most encouraging results in the Ricardo research laboratories.

In conclusion the author states that there is today no real necessity for making a distinction between aeronautical research and any other scientific research. It is the author's opinion that many of the distinctions and barriers which now exist could be broken down with benefit to science in all its forms. The very multiplicity of series and of form of presentation of scientific reports creates a physical barrier to effective reading, which is particularly serious to those who have not large library facilities at their command. The researches mentioned in this paper are mostly included in the reports and memoranda series of the Associate Air Research Committee of Great Britain, and in the technical-report series of the National Advisory Committee for Aeronautics of the United States, and there is little or no reason why a number of them should be confined to aeronautic publications. A good step toward simplification would be made if the reports of all publicly financed scientific work were published in a uniform manner in a single series. (Squadron Leader A. Ferrier, Aeronautical Engineering Division, Department of National Defense, Ottawa, Ont., paper before the General Professional Meeting of the Engineering Institute of Canada, Feb. 8, 1933, abstracted through *The Engineering Journal*, vol. 16, no. 4, April, 1933, pp. 178–185, 12 figs., *d*)

The Paddle-Wheel Airfoil System

THE author deals with three planes of the direct-lift type. As to the first, the invention of which is credited to Dr. Adolf Rohrbach, of Berlin, the author repeats what has been previously published in the *New York Evening Post*. He considers next the helicopter and is apparently inclined to believe that one could be built. In his opinion, however, the paddle-wheel principle is more promising than that of the helicopter; in fact, he believes it to be extremely promising, and thinks that the mechanical difficulties of such a construction, though important, are not insuperable.

Among the American workers in this field the author mention H. H. Platt and I. B. Laskowitz. The Platt device was tested first in the wind tunnel of the Massachusetts Institute of Technology and then in the wind tunnel of the Daniel Guggenheim School of Aeronautics at New York University. The promising results achieved in the tunnel and his theoretical work enabled Platt to interest the N.A.C.A., and a full-scale rotor is to be built and tested at Langley Field. The principles of the Platt invention are covered in a United States patent.

The Platt construction embodies a train or gear drive to two airfoil systems mounted at either side. It is intended to use a clutch mechanism which will allow the paddle wheels to auto-rotate when desired. The wing blades are to be few and of rather narrow form; the airfoils will be supported and pivoted at a point carried around by the driving system; the feathering will be achieved by spiders or rods carried around by the airfoils, and these controlling spiders or rods will be set automatically by a combination of two eccentrics. Controls will be provided which will allow the feathering to be varied in flexible fashion for the two paddle wheels, either jointly or separately.

In the Laskowitz design a single eccentric is employed and the control of feathering is achieved by moving a single eccentric

either vertically or horizontally so that eccentricity of any direction or magnitude can also be achieved.

The author next briefly refers to a wheel shown in wind-tunnel-model form at the recent Paris Show and called the Strandgren wheel, as well as to the Kirsten cycloidal propeller described in the Transactions of The American Society of Mechanical Engineers, Vol. 49–50 (1927–28), paper AER-50-12. The original article contains extensive quotations from the Platt and Laskowitz patents. (Alexander Klemin (Mem. A.S.M.E.), in *Aviation Engineering*, vol. 8, no. 2, Feb., 1933, pp. 5–8 and 30, 3 figs., *d*)

ENGINEERING MATERIALS

Reinforcing Bar

THIS type of reinforcing bar has been developed as a result of an investigation conducted by the author in the engineering laboratories at the University of Iowa and differs from existing types in that the deformations are small and so closely spaced that they might properly be called crenulations.

The theory of the crenulated type of bar rests on securing a better balance between the shearing area and the bearing area presented to the concrete. Fig. 1 represents a longitudinal section through a deformed bar. The resistance to slipping is increased by the presence of the projections. To obtain maximum resistance, the projections should be spaced so that the shearing strength of the concrete along section *AB* will equal its bearing strength on the edge of the projection *AC*, which in turn should equal the shearing strength of the steel along section *DE*. It is also important that the angle of inclination of the bearing surface *AC* to the axis of the bar should be sufficient to prevent wedging action from splitting the concrete.

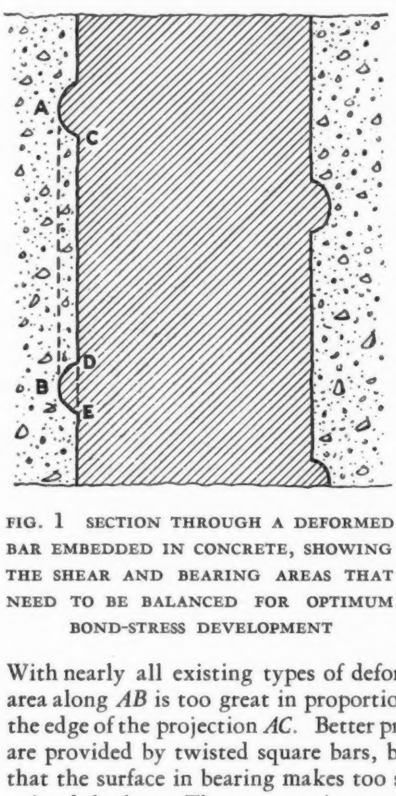


FIG. 1 SECTION THROUGH A DEFORMED BAR EMBEDDED IN CONCRETE, SHOWING THE SHEAR AND BEARING AREAS THAT NEED TO BE BALANCED FOR OPTIMUM BOND-STRESS DEVELOPMENT

With nearly all existing types of deformed bars, the shearing area along *AB* is too great in proportion to the bearing area on the edge of the projection *AC*. Better proportions in this respect are provided by twisted square bars, but they have the defect that the surface in bearing makes too small an angle with the axis of the bar. The two requirements seem to conflict if the area of the bar is not to vary along its length, which is an important practical consideration. The difficulty can be overcome by making the projections quite small compared to the diameter of the bar. In the absence of accurate information as to the relative bearing and shear, the best dimensions for the small deformations or crenulations cannot be determined. However, bars that only roughly approximate a proper balance give bond stresses that exceed by a considerable margin those obtained for ordinary deformed bars, as is evident from the data.

The tests referred to in the article show that at slips of 0.01 in. or less the crenulated bars develop stresses about 50 per cent higher than do the ordinary deformed bars. The tests also indicate that the crenulated bars are less likely to split the concrete than ordinary deformed bars. (Chesley J. Posey, Instructor in Mechanics and Hydraulics, University of Iowa, abstracted through *Engineering News-Record*, vol. 110, no. 15, April 13, 1933, p. 461, 2 figs., *d*)

Beryllium-Copper

REFERENCE has been previously made (MECHANICAL ENGINEERING, January, 1933, pages 44–45) to the use of beryllium-copper alloys for the manufacture of springs. The present author gives some further information on the subject and also says that annealed wires of the smaller sizes may be woven into cloth and subsequently heat-treated. Such cloth then becomes stiff and strong since the tensile strength of the individual strands is in the neighborhood of 140,000 to 160,000 lb per sq in. Tubes have been made in most commercial sizes, although not in large quantities. One of the principal uses is in cold-drawn Bourdon tube employed in the manufacture of pressure gages.

When either annealed or cold-wrought beryllium copper is subjected to low-temperature treatment from about 275 to 300 C for a period of two hours, the strength, hardness, and allied properties are improved greatly. For example, the tensile strength of annealed beryllium-copper will be increased by heat treatment from about 60,000 to 160,000 lb per sq in.; hard-rolled sheet would increase in like manner from 165,000 to 210,000 lb per sq in. By the same treatment the conductivity is increased by 2 per cent or more of the international annealed-copper standard. The elastic limit and modulus of elasticity likewise are affected beneficially.

The alloy may be hot-forged or hot-pressed at temperatures between 720 to 820 C, depending upon the beryllium content. After hot-forging, the part is annealed at 800 C, quenched, and heat-treated at 275 to 300 C. The Brinell hardness then will be about 350 and the tensile strength about 150,000 lb per sq in. (C. H. Davis in *Machine Design*, vol. 5, no. 3, March, 1933, pp. 23–24, 3 figs., *d*)

FUELS AND FIRING (See also Internal-Combustion Engines: Velocities of Combustion of Gasoline-Benzol-Air Mixtures in High-Speed Ignition-Type Motors)

Hydrogen as a Commercial Fuel for Internal-Combustion Engines

THE authors (one of whom is connected with a German company) discuss the various methods of producing hydrogen and the possibilities of the use of hydrogen alone or with oxygen as a fuel for various commercial purposes. For the manufacture of hydrogen they refer to electrolyzers and mention specially the Pechkranz electrolyzer. It is employed in Norway for making very pure hydrogen for ammonia synthesis and absorbs 5 kwhr per cu m of H_2 at 15 C and 760 mm of mercury. The hydrogen is formed at atmospheric pressure and ingenious use is made of the heat in the cooling water for production of make-up distilled water.

As a source of power for the manufacture of hydrogen, the author considers chiefly off-peak load of water-power plants, as well as large steam-power plants, pointing out in connection with the latter that while there is no free power going to waste during off-peak hours, the cost of banking fires and getting up

steam in large boilers must be considered. Mention is also made of the Noeggerath electrolyzer, which is of the diaphragm type, the electrolite being a 23 per cent solution of KOH. The cell is enclosed and the pressure allowed to rise. A suitable arrangement equalizes the pressures of hydrogen and oxygen available and the pressure can be allowed to rise to enormous figures, 1000 atm having been successfully experimented with. Suitable working pressures are from 5000 to 7500 lb per sq in., being convenient pressures for refilling storage bottles at 3000 lb (200 atm).

The cost of hydrogen made by this method depends on several factors:

(1) The cost of off-peak-load power.

(2) The number of hours which constitutes off-peak-load time, e.g., on an underground railway it is about 4 hr in the night and on the grid it would be nearer 12 hr. Obviously an installation to provide a definite quantity of gas will require three times the capital expenditure on electrolyzers in the former case.

(3) The ability to sell oxygen.

Figures given in the original article show a cost of £4/17/8 for 1000 cu m of hydrogen, not counting the oxygen. It is not quite clear what the real economic possibilities of the oxygen are. A difficulty in using liquid hydrogen is that for the same number of heat units it has four times the volume of gasoline.

The authors discuss the question of the hydrogen engine without reporting actual tests on existing units except for some indicator diagrams and a statement that in actual practice the output from the hydrogen engine approaches to the air-standard cycle in theory. They also mention the oxygen-hydrogen engine, and the use of hydrogen as a promoter of ignition in gasoline engines and as a primer in the Diesel engine. (Rudolf A. Erren and W. Hastings Campbell, paper before *The Institute of Fuel*, March 21, 1933, abstracted from advance copy, 7 pp., 2 figs., *dg*)

Firing With Unground Coal Dust

THE author has carried out a considerable amount of work on the combustion of unground coal dust in large boiler furnaces. The economic advantage of this type of firing lies in the elimination of the overhead and operating costs of the grinding mill and the fact that without any auxiliary installations it is possible to burn the dust and finely broken material of 2 to 4 mm (0.078 to 0.157 in.) grain size obtained in the preparation of coal for shipment. In the utilization of this kind of fuel in pulverized-coal-fired plants, its efficiency is said to be so high that it is not exceeded even by that of the most modern methods of grate firing. The present article deals with the application of similar processes and machinery to small and medium-sized boiler units.

The essential elements in firing unground coal dust have been investigated by Hold. In brief, the furnace of a pulverized-coal-fired plant of the usual design has no grate, but instead a bottom of fireproof brick, provided with ports for the admission of the air of combustion. The untreated dust is introduced into the furnace with the necessary amount of air, the coal being preferably burned in suspension. The coarser particles that are too big to burn in suspension fall on the incandescent bottom where they are consumed. The air flowing through this material from the bottom sufficiently agitates the fuel so that there can be no piling up of the grainy particles. Furthermore, the incoming air causes a motion which assists in separating the ash from the coal particles. Simultaneously, the air cools the bottom and delays its destruction by the high temperatures prevailing there.

The first tests were carried out in 1931 on a vertical water-tube boiler having a heating surface of 517 sq m (5563 sq ft) and proved to be quite successful. Since then considerable work has been done and certain improvements have been introduced. Among other things, particular attention is now paid to the proper distribution of the injection air and air flowing through the bottom. Next, the system has been developed so that it can be applied to small boiler units and to fire-tube boilers in which the very moderate dimensions of the furnace and the shortening of the path of the flame resulting therefrom make it difficult to secure a sufficient supply of air for good combustion. It is claimed that the results obtained with the unground coal dust have been eminently satisfactory.

Among other things, the author reports an evaporation test on an inclined-tube boiler with a heating surface of 326 sq m (3508 sq ft) equipped with a superheater having an area of 110 sq m (1184 sq ft) and a smooth-tube preheater of 216 sq m (2324 sq ft). The furnace has a capacity of 97 cu m (3425 cu ft) so that there was about 0.3 cu m (about 1 cu ft per sq ft) of furnace space for one square meter of boiler heating surface. These ratios were approximately the same as those in the test on a larger furnace previously referred to. In a 6-hr test with normal load on the heating surface of the boiler, the author used unground bituminous coal dust containing 22 per cent of volatile constituents and 72.6 per cent of residue on a 70-mesh sieve and 53 per cent residue on a 30-mesh sieve.

The output was 37.22 kg of steam per sq m per hr (7.6 lb of steam per sq ft per hr), the furnace output 100,000 cal per cu m per hr (11,200 Btu per cu ft per hr), and the efficiency 82.2 per cent. The author reports several other tests on both small and large boilers.

The author discusses in some detail the matter of air supply and proceeds to state that the success of firing with unground coal dust in water-tube boilers led to an attempt to apply the same method to fire-tube boilers. The fact that the first tests were not successful is ascribed to the excessively small size of the furnace. Even when this was increased, the operation was not entirely satisfactory. In conclusion it may be stated that the construction of the furnace of the kind described is simple and its installation may be recommended where coal dust and breeze are available of dimensions substantially such as have been referred to at the beginning of this article. (O. Haller, Chief Inspection Engr., in *Gluckauf*, vol. 69, no. 4, January 28, 1933, pp. 82–85, 4 figs., *dp*)

Power Alcohol

IT IS POINTED out that one of the reasons why alcohol can be considered as a commercial fuel is that in some countries industrial alcohol today is made in large highly organized factories by the fermentation of the cheapest possible carbohydrate material, in particular, black-strap molasses, which is transported from the place of origin in tank steamers and stored in large tanks. It is pumped and handled like oil at a minimum cost. The alcohol produced is separated from the fermentation mash in a continuous still with minimum expenditure of steam and can be concentrated in one continuous operation to an anhydrous product containing 99.99 per cent of alcohol.

A new method for the production of absolute alcohol is based on the work of Prof. Sydney Young, namely, that a ternary mixture of three liquids will vaporize at a lower temperature than any one of them singly or any mixture of two of them. Young found this in the laboratory nearly thirty years ago. This makes it possible to add to an aqueous alcohol a third liquid, such as benzene, or preferably benzene with a

light high-boiling gasoline from a particular fraction, and drive off all the water as a ternary mixture, leaving dry or absolute alcohol behind at the lower plates of the still. The ternary mixture when condensed separates into two layers, the aqueous being rejected after recovery of such alcohol as it retains and the benzene being returned to the circuit.

In Germany the latest attempt at a home-made motor spirit is to use a mixture containing 10 per cent of absolute alcohol, 10 per cent of synthetic wood alcohol made from water gas, 10 per cent of benzol from coke ovens, 35 per cent of gasoline made by hydrogenation of "coal oil," and 35 per cent of imported gasoline. In Germany about two-thirds of the alcohol is made from potatoes, the rest coming from molasses, grain, and paper-pulp liquors. (Editorial in *Nature*, vol. 131, no. 3306, March 11, 1933, pp. 341–343, *g*)

Pulverized Coal and Colloidal Fuel

THE following comparative figures are given for various fuels per therm:

Electricity at $^1/_2$ d per unit, 1s 3d per therm
Gas at 1s 6d per 1000 cu ft, 520 Btu, 3.5d per therm
Oil of 19,000 Btu at 50s per ton, 1.4d per therm
Pulverized coal from coal of 13,500 Btu, at 13s 6d per ton allowing all preparation and operating costs, 0.6d per therm.

The following advantages are claimed for colloidal fuel as compared with coal or oil: In many respects, colloidal fuel is actually superior as a boiler fuel even to straight oil. The following data refer to colloidal fuel composed of equal weights of coal and oil of 14,000 and 19,000 Btu calorific value respectively. Colloidal fuel is safer than oil, and its steam-raising efficiency may be better than either the coal or the oil burned separately. A minimum of excess air is required—no more than for oil. Owing to the presence of the solid particles of coal, a more intensely radiating flame is obtained, thus improving heat transfer. The ash in colloidal fuel made with a good quality of coal may amount to less than $1^1/_2$ per cent.

On board ship space is a matter of supreme importance and colloidal fuel is more compact than either coal or oil. A ton of colloidal fuel would occupy approximately 32 cu ft of hull space, as compared with 37 cu ft for oil fuel and 43 cu ft for coal. Moreover, for a given volume, colloidal fuel is the richest in heat units. The bunker space required for a ship burning colloidal fuel will be 10 per cent less than with a sister ship using straight oil and 50 per cent less than a similar coal-burning ship of equal steaming radius.

An interesting feature of colloidal fuel is that its specific heat is about 26 per cent less than that of straight oil. Consequently, the amount of heat required to give mobility to the fuel for atomizing in the burners will be 26 per cent less than for a ship burning straight oil.

Because colloidal fuel is heavier than water, it is claimed that an additional factor of safety against fire is provided for the following reasons: (1) Any fuel leakage will sink to the bottom of the bilge water and is inaccessible to ignition; (2) Water may be used as a seal to prevent evaporation in storage. An oil-coal mixture is not a true colloidal solution, as the size of the coal-dust particles used in commercial practice for pulverized-fuel firing are enormously greater than the largest particle in a true colloidal solution. We have here, therefore, what is known as supra-colloids, containing solid particles that, when suspended in a fluid, tend to settle at the rate predicted by Stokes' law. The particles may be stabilized to some extent by the introduction of stabilizing agents, such as certain soap solutions.

Professor Gillet in France formed a gel directly between the coal and oil without the addition of a third substance and obtained completely stable suspensions of 80 per cent of coal in anthracene oil. Coal may also be reduced to particles of colloidal size by the process known as peptization. This process consists in the splitting apart of the coal particles and may be accomplished physically by the action of solvents, such as pyridine, or chemically by agents, such as chlorine. A fuel made on these lines, which has been given the name of "Fliesskohle," or fluid coal, is being produced in Germany in a small commercial plant, but no conclusive data are available as to its stability and cost of production.

The higher the price of oil in relation to coal, the greater, of course, will be the margin available for the production of colloidal fuel on an economical basis compared with oil fuel on a heat basis. For land consumption, where the price of oil fuel may be in the neighborhood of 60s per ton or more, a wide difference exists over the price of raw coal, which enhances the possibility of developing the use of colloidal fuel in places where oil is now used, such as in central-heating plants. In marine work, however, the price of fuel oil for bunkering is usually far below that for land consumption and may be as low as 25s to 30s per ton. The diagram in Fig. 2 shows the available margin to cover the manufacturing price on a heat basis to straight oil at various prices, from which it will be seen that with the very low current price of oil for marine work, a margin of only 3s or so per ton is available to cover the total production costs of colloidal fuel from the raw materials. (Commander H. D. Tollemache, lecture before the South Wales Institute of Engineers, at Cardiff, abstracted through the *Iron and Coal Trades Review*, vol. 126, no. 3395, Mar. 24, 1933, pp. 453–454, 3 figs., *ep*. Compare for a similar abstract *The Steam Engineer*, vol. 2, no. 7, April, 1933, pp. 293–295)

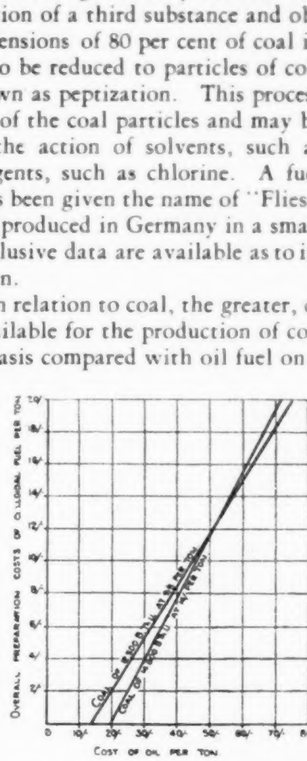


FIG. 2 MAXIMUM PERMISSIBLE COST OF PREPARING COLLOIDAL FUEL (50–50 MIXTURE)

Utilization of Briquet Waste With a Simple Supplementary Powdered-Coal Firing

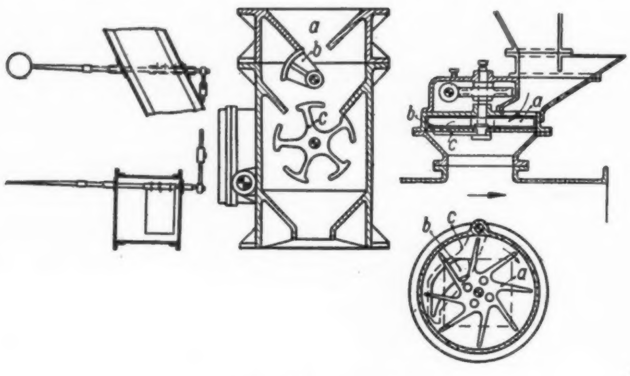
IN HANDLING briquets, a certain amount of breakage and pulverization takes place, particularly with lignite briquets. The amount of this breakage may be so great as to interfere with proper firing.

In a majority of installations the briquet breeze is either delivered to the grates or is set aside and later used for banking. If the breeze is put on the grates, it piles up as a result of non-uniform distribution. Where the resistance to the flow of air for combustion is too great, combustion is delayed, with the result that losses from unburned fuel going to the ashpit, slagging, and an unsatisfactory carbon-dioxide showing may become quite material. The use of the breeze for banking is of secondary importance because of the small amount of coal that can be used in this way. It would appear, therefore, that neither of the two methods referred to is an economical way to utilize this expensive fuel.

In tests carried out by the author with a view to utilizing briquet breeze by supplementary firing, the first step was to

load the grate with good coal so as to obtain good combustion.

The chutes by which the briquets were delivered from the coal bunkers *a*, Fig. 6, to the grate were provided with slots *d* on the under side separated from the main chute *b* by a bar *c*, 10 mm (0.39 in.) wide. The main slots were equipped with signaling devices, Fig. 3, to indicate the bridging over of the briquets. This was necessary because the briquets, particularly where large or angular shapes were used, would frequently pile up. In the majority of cases this piling up was noticed only when an



FIGS. 3, 4, AND 5

(Fig. 3 (left) Signal device to indicate piling up of briquets on the conveyor; Fig. 4 (center) Device for distributing untreated briquet breeze; Fig. 5 (right) Improved form of Fig. 4.)

inspection of the fire showed that all of the coal had been delivered from the hopper. In this apparatus the coal accumulating in the chute presses down a rotary flap loaded on its outer face by a counterweight, Fig. 3. As soon as the coal begins to bridge, the pressure exerted on the flap is indicated by means of a signal disk on the outside. If the coal is pushed forward, the signal disk comes down, which indicates that the chute is again in operating condition.

The broken coal and powdered material falling into the lower chute is then delivered to the pulverized-coal bunker *h*, Fig. 6. An attempt was first made to deliver the broken material without any further preparation to the firing nozzle *k* in the furnace, using the distributing manifold *i* and a blower. The coal is blown sharply downward from the rear wall of the furnace, and therefore passes first through the combustion gases coming from the end of the grate that are rich in excess air. The injection air stream mixes thoroughly with these gases with the result that good combustion is obtained. Radiation from the fuel bed produces rapid ignition of the particles of the coal.

The original device for the distribution of the powdered coal, Fig. 4, led to certain difficulties. It was therefore redesigned and the device shown in Fig. 5 was substituted. In the design shown in Fig. 5 the breeze is pushed by the star wheel *a* over the slot *b*. Under the slot is located the screen *c*.

When operation with subsidiary firing was started it was found that with breeze in its original state the improvement in the output of the boiler lasted for only a very short time. The numerous large lumps of breeze could not be carried by the upward stream of combustion gases and fell on to the fuel bed. Because of lack of time they did not burn in suspension but were distributed over the fuel bed on the grate. When the amount of breeze was large, the accumulation on the fuel bed became so great that combustion was reduced to an extent where further injection had to stop until conditions were corrected. This materially affected the efficiency of the boiler.

It was found that for proper subsidiary firing it was necessary for the fuel to be in such a fine state of subdivision that the major part of it would burn in suspension. Moreover, it was necessary for the number of particles falling on the fuel bed to be limited and of such size that the performance of the grate would not be unfavorably affected. Since the furnace in the case of a normal water-tube boiler is usually of comparatively small size, the fuel particle must not be greater than 0.15 mm (0.00591 in.) if it is to burn in suspension. It is therefore necessary to grind the briquet breeze before it is injected into the furnace. The cost of preparation and grinding is a dominating factor in the economy of any pulverized-coal firing. Because the cost of grinding increases with the fineness, it is desirable to select as large a coal particle as possible.

The author states that jointly with the firm of Matthiass, of Erfurt, he designed a low-cost grinding mill that occupied a small amount of floor space. This mill is centrally located in the boiler room as shown in Fig. 6. In order to increase the quantity of the breeze, the space *c* between the main chute and the breeze chute was increased in width to 20 mm (0.78 in.). Instead of the original pipe connections between the breeze chute and the bunker *h*, sheet-metal conveyor worms *e* were installed, delivering the breeze from all the boilers to the grinder bunker. After the coal has passed the grinding mill *f*, Fig. 6, the conveyor worms *g* deliver the pulverized material to the powdered-coal bunkers *h*. The arrangement is such that the delivery of the coal can be limited to boilers in actual operation. No attempt has been made to dry the breeze and no trouble has occurred even when the moisture in the coal has been as high as 16 per cent.

A description of the mill for grinding briquet breeze is given in the original article. In the operation of the plant it was found that subsidiary firing made the boiler plant much more flexible than it was before. The value of the subsidiary firing, in addition to a more economical utilization of the fuel, lies in the more rapid steaming of the boiler. Thus it has taken not quite 4 min to bring a vertical water-tube boiler from an output of 20 kg per sq m per hr to 46 kg per sq m per hr. Where sudden and great variations of load are to be expected or where interruptions in the operation of the boiler are likely to occur, this is of great importance, as the output of the boiler can be almost instantly accommodated to variations in the demand for steam. It has been found that when subsidiary firing is cut off, the boiler output rapidly falls back to its previous state. It has also been found that with a boiler of a given type and various kinds of coal, the limits within which subsidiary firing

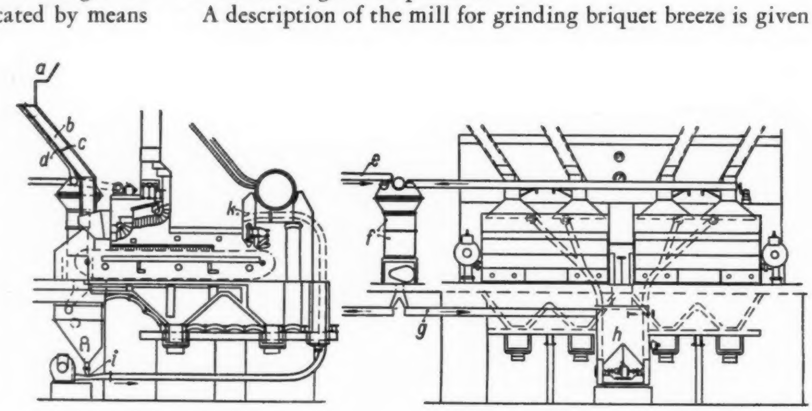


FIG. 6 DIAGRAMMATIC ARRANGEMENT OF THE SUBSIDIARY FIRING UNIT

is economical are quite definite. No further increase in production can be obtained at all, or it can be obtained only at excessive additional cost.

In the boiler plant with which the author has been dealing, a briquet poor in bituminous components was used. It burns slowly and ignites with difficulty. The limit of output is at about 28 kg per sq m per hr (5 lb per sq ft per hr). During the period of supplying the coal dust to the boiler by blast, the furnace temperature rose about 100 C (180 F), with the result that the coal on the grate ignited faster and burned better. It would appear, therefore, that the improvement in boiler operation is due not only to the fact that additional fuel is supplied by subsidiary firing, but also to the better performance of the fuel on the grate because of an increase in temperature. It is said that no material effect on the furnace walls was produced by the application of the subsidiary firing.

The original article gives detailed data of five tests on a vertical water-tube boiler of 450 sq m (4843 sq ft) heating surface with a traveling grate having an area of 18.68 sq m (194 sq ft). The first three tests, which are not reported in detail because of lack of space, would indicate that it pays to remove the breeze and carry on the firing with clean coal only. (Konrad Weiss, *Die Waerme*, vol. 56, no. 12, March 25, 1933, pp. 179–182, 7 figs., *dp*)

INTERNAL-COMBUSTION ENGINEERING (See also Fuels and Firing: Hydrogen as a Commercial Fuel for Internal-Combustion Engines)

Velocities of Combustion of Gasoline-Benzol-Air Mixtures in High-Speed Ignition-Type Motors

THE author describes a new method which he claims makes it possible to measure certain phenomena of high-speed combustion. The method involves the use of an oscillograph. The author claims to have been able to determine the effect on the velocity of combustion of varying the proportions in the mixture, the effect of turbulence in the combustion chamber, the fuel used, and the compression ratio. The state of turbulence of the mixture has been measured.

The author believes that if one assumes that in order to ignite a particle of fuel a definite amount of energy of activation must be supplied to it and that the time during which this process of supplying energy takes place determines the velocities of combustion, it will be found that for each fuel there are two ways to modify this transfer of energy, namely, by varying the magnitude of the source of energy and by varying the duration of the transfer of energy. If it is assumed that this is so, all the influences affecting the velocity of combustion may be classified and considered from this point of view. While bomb tests have shown that variation in the source of energy affects only slightly the velocity of combustion, the shortening of the time of transfer of energy acquires an increasing importance. In the present tests the author claims to show the dominating influence of the turbulence in the mixture which produces this shortening of the duration of energy transfer. Whether one still holds to the present views on the kinetic energy of the fuel or seeks an explanation of the facts in chain reactions, turbulence, particularly through increase of the area of the flame (because this permits an increased transfer of energy or a more rapid combination of the intermediary members produced in the course of chain reactions), materially accelerates combustion.

The recognition of these facts is not materially affected by the circumstance that in the velocities of combustion measured in the course of the tests described by the author were included also the velocities of interpenetration of the gases produced by the burning particle of the mixture. These velocities of interpenetration are affected in exactly the same manner as are the velocities of combustion, as both depend on the transfer of energy by the temperature of combustion or by turbulence.

The author believes, therefore, that he may be justified in deriving in the first approximation his concepts concerning the velocity of combustion as a function of the transfer of the energy of activation.

Because of the effect of the velocities of interpenetration, the results obtained by the author, which cannot be reported here because of lack of space, apply only to cylindrical combustion chambers where the spark plug is located on the side. In particular his results do not apply to cylinders with Ricardo valves. (Kurt Schnauffer, Doctor of Engineering thesis at the Berlin Technical High School, published by Verein deutscher Ingenieure Bookstore in 1931, pp. 5–12, 20 figs., *e*)

Rotary-Piston-Type Gas Engines

THIS is an extensive article dealing with the use of liquids to take the place of the conventional metal piston in internal-combustion engines. The author presents some historical data on this subject, indicates the reasons for previous failures of this type of apparatus, and proposes what he considers to be a workable design. Because of the length of the original article, only a portion of it is abstracted this month. The remainder will be abstracted in a subsequent issue.

The author points out that it was realized at an early date that a liquid such as water, when used as a piston, would have certain important advantages. In particular it would require no lubrication, would give a high volumetric efficiency, and would be noted for its comparatively low consumption of energy, due to the fact that compression would take place in the presence of "cooling water."

In some ways the expectations for this type of engine have not been realized. Thus, for example, it has been found that the transfer of heat from the air to the water level has been surprisingly small and that the compression line barely differs from a pure adiabatic line. This is mainly due to the fact that because of the poor heat conductivity of the water, the heat stays at the surface separating the air and water and scarcely penetrates below the actual surface.

The arrangement was apparently first tried out in a double-acting horizontal compressor, and among other things it has been found that as the number of strokes per unit of time increased, the useful output of the compressor gradually decreased and the machine finally ceased working entirely. One of the reasons was pointed out by A. Riedler in 1899 in his book on high-speed operation. According to this explanation, at higher speeds a strong up-and-down movement is developed in the water level, with the result that an air-water emulsion is produced, so that ultimately the plunger is simply compressing and decompressing an elastic water-air mixture and no fresh air flows through the valves.

The author presents another explanation. Because of the action of the crankshaft, the liquid constituting the piston is forced upward with a certain acceleration. When the crank reaches the upper dead center, the liquid must begin going down, and if the upward acceleration is greater than the downward acceleration due to gravity, the liquid can no longer move as a uniformly continuous mass. The particles of the liquid therefore separate so that the air penetrates the liquid, with the result that at a certain critical speed the compressor ceases working.

The first attempt to remedy this condition was to make the cross-section of the water much greater than the cross-section of the plunger piston in order to reduce the stroke of the liquid and hence its acceleration. This resulted in such an excessively low number of revolutions that the idea of a water piston was given up for the time being.

The author refers next to the liquid-piston double-acting two-stroke-cycle gas engine built by Adolf Vogt and patented in Germany (No. 137,832). This proved to be a failure because the designers ignored the law governing the behavior of water masses moving in stationary cylinders and acting as power pistons. This law is briefly stated, as follows: The acceleration b of the level of the liquid in the upward direction must not be greater than the acceleration due to the gravity; i.e., $b < 9.81$ m per sec per sec (32.2 ft per sec per sec). From this the author derives the following rule of design: The throw of the crank governing the "stroke" of the water level must be so proportioned (in proper relationship with the other dimensions of the machine which affect the variation

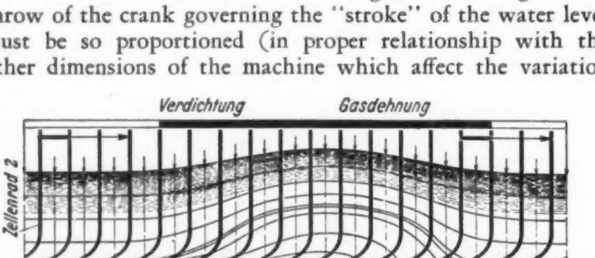


FIG. 7 PENDULAR-FLOW MACHINE

(*Verdichtung* = compression; *Gasdehnung* = gas expansion)
(The water flows through a stationary guide ring between two rotating cellular wheels mounted on a common shaft. The water is moved back and forth by alternating gas explosions, the water giving up the excess of energy imparted to it to the cellular wheels. In each cellular wheel the water piston moves in and out like a pendulum. The short arrows indicate the pressures on the water pistons.)

of the level during the stroke) that the acceleration of the level at the uppermost position of the water surface must be less than the oppositely acting acceleration due to gravity. If the radius of the crank is R, the length of the connecting rod L, the cross-section of the plunger piston F_k, the area of the water surface at its highest position F_w, and the speed of the machine n revolutions, giving an angular velocity of $\omega = \pi n/30$, then the following equation determines the acceleration of the water level:

$$b = R\omega^2\left(1 \pm \frac{R}{L}\right)\frac{F_k}{F_w} < 9.81 \text{ m per sec per sec}$$

This does not mean that in the case of machines of this type, with stationary cylinders and moving water pistons, total absence of splashing is insured by following such a single rule of design as this just cited. It does mean, however, that the performance of the machine is affected by its dimensions and also its revolutions, and that no matter how the other dimensions of the machine have been selected, it will work only up to a certain predetermined critical speed of rotation.

From this it follows that in order to obtain a water-piston machine capable of operating at high speeds, the conventional form of the reciprocating machine with stationary cylinders must be abandoned in favor of a cellular wheel with individual water pistons, and instead of a crankshaft drive, one especially suited for this purpose that will make it possible to absorb and reject the work of the gas from and to oscillating and rotating water levels that are under the influence of centrifugal force. Such a drive may be hydraulic, built something like a "pendulum ring." Such a ring is shown (extended) in Fig. 7 taken from a previous publication by the author of this paper. In this case two cellular wheels are provided. Water flows through a stationary guide ring located between two rotating cellular wheels held on a common shaft. The water is driven by alternating gas pressure and gives up its excess energy to the rotating wheels. In each individual wheel there is therefore a certain amount of oscillation of the water piston. The short arrows in the illustration show the pressure on the water pistons.

The following law is proposed as an expression of the condition that permits the maintenance of workability of the rotating and oscillating surface of the water: The inwardly directed acceleration of the water surfaces must not be greater than the oppositely directed acceleration due to centrifugal force. From this the following rule of design has been formulated:

The length of the path of water for each double piston whose two parts are connected by the guide passages must be such that, for a given maximum acceleration pressure moving the double piston considered jointly with the minimum distance of the water level from the driving axis, the maximum explosion pressure to be expected will not produce an acceleration of the level of the liquid greater than the acceleration due to the centrifugal force available. It would appear therefore that if such a double piston has a uniform cross-section over the entire length of the water path L, if the acceleration due to centrifugal force is b, if the force produced by the acceleration is P, and if the level of the liquid exposed to the gas pressure is at a distance R_i from the member of the machine producing the rotation, then

$$b < R_i\omega^2 \text{ and } L > \frac{Pg}{\gamma R_i\omega^2}$$

(The meaning of γ is not specified.)

From these relations it would appear that as regards absence of splashing, the pendulum-ring machine is even more difficult to design than the water-piston machine with stationary cylinders and crankshaft drive, because of the fact that in the former a critical maximum pressure must be considered in addition to the critical speed of rotation. Moreover, for certain reasons explained in the original article, the matter of starting of such machines is also fraught with considerable uncertainty. Nevertheless, the pendulum-ring machine type must be carefully considered in connection with the future development of the cellular-wheel gas engine.

As regards safety from splashing of the rotating surface of water, the logical step is to replace acceleration due to gravity by acceleration due to centrifugal force, the possibility of which was at first generally questioned. The absence of splashing can be obtained by the use of proper lengths and cross-sections of the water pistons, even if this is possible only for given maximum pressures and minimum revolutions per unit of time.

In the inner half of the stroke, i.e., the one directed toward the axis of rotation, the gas spaces must be separated from each other as well as outwardly by rigid walls. If this is done, they will be found to lie in the region of the maximum gas pressures and gas temperatures and will be completely water-sealed. The partition walls between the single cells spreading

out from the gas chambers must be located radially outward, which permits better control of the water level than curved walls. The combustion spaces must be scavenged axially, as with such an arrangement the "jumping" of the water level may be avoided. The ports for exhaust, scavenging, and admission must be located in the "outer" half of the water-level stroke, as with such an arrangement the excessive water can run out over the edge of the exhaust ports.

Instead of being moved by a pendulum ring, the individual oppositely closed water pistons of a cellular-wheel gas engine can also be moved by a rotary piston drive controlling the inward and outward oscillations of the water pistons. Of course, not every rotary piston drive which can perform the motion is suitable for rotary-type engines, because even in the rotary piston it is not the gas pressures which hold together the individual water pistons. Only such drives can be used as do not impose upon the water level greater inward accelerations than the oppositely directed centrifugal accelerations. For every type of "wet" rotary-piston drive the acceleration of the water level is a function of the eccentricity A, angular velocity ω, and dimensions of the stator and rotor, such as, for example, exist between the outer water surface F and the inner water surface f of Fig. 8.

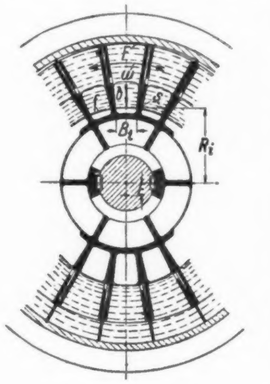


FIG. 8 NOTATION USED IN FORMULAS FOR THE CELLULAR WHEEL OF A "WET" ROTARY-PISTON MACHINE

This relationship may be expressed by a definite drive constant α, depending on the shape and method of driving of the rotary pistons and having for the simplest rotary-piston drive shown in Fig. 8, the value $\alpha \approx F/f$ in the formula for the inwardly directed acceleration b of the water level

$$b = \alpha\omega^2 E$$

In order to make the individual pistons free from splashing one must observe the rule

$$b < R_i\omega^2$$

This can be achieved by following the rule of design, which is as follows:

$$(F/f)E < R_i$$

which means that contrary to the case of water-piston machines with stationary working cylinders and also contrary to the rotary-type pendulum machines, in "wet" rotary-piston machines, freedom from splashing on the liquid surface does not depend on the gas pressures, or on the amounts of water in motion, or on the number of revolutions of the machine per unit of time, but depends entirely on the dimensions of parts of the rotary-piston drive, particularly on the correct relationship between the eccentricity E and the minimum distance R_i of the level of liquid from the axis of rotation. (Abstract of first part of an article by Prof. G. Stauber, *Zeitschrift des Vereines deutscher Ingenieure*, vol. 77, no. 15, April 15, 1933, pp. 393–399, 18 figs., *dhA;* an abstract of the second part will appear in an early issue of MECHANICAL ENGINEERING)

7-Hp Two-Stroke Airless-Injection Engine

THIS engine is of the crankcase-compression type. To overcome the usual objections to this type of engine, the form of the piston crown is such as to cause the air entering from the transfer port to sweep up the opposite wall of the cylinder. As the air approaches the top, it is diverted by the shape of the head to sweep down the wall containing the ports. In the position of the piston shown in Fig. 9 the bulk of the residual products will have been driven out through the exhaust port, though a small portion may have mixed with the incoming air as shown by one of the arrows. By the time the piston overruns the exhaust port, however, the contents of the cylinder will consist of practically pure air in a state of rotation, and as the volume is reduced, the speed of rotation will increase. Just before the top dead center a sudden further increase of speed will occur due to the reduction in volume caused by the left-hand part of the piston approaching the crown, and when the top dead center is actually reached, the compressed air will be whirling at high speed past the fuel jet, insuring an intimate mixture of air and fuel when the latter is introduced. The engine is built as a single-cylinder stationary unit. The connecting rod is a drop forging. Both its large and small end bearings are of the roller type. The piston pin is located by spring rings. In order to reduce vibration to a minimum, both the crankshaft and piston pin are of large diameter and the shaft is well supported. The cylinder is provided with a detachable head having the atomizer in the center. The transfer port is cast in the cylinder. The fuel pump is of the Deckel type. The plunger is directly operated by a tappet provided with a roller at the bottom bearing on a cam connected to the engine crankshaft. The fuel injection is regulated by the action of a spill valve which is operated by an adjustable interceptor plug screwed into the rocker arm. The point of cut-off is actually regulated by varying the position of this plug with regard to the spill valve, the rocker arm being mounted on an eccentric shaft for this purpose and the shaft being connected to the governor. Data of tests are given in the original article. (*Engineering*, vol. 135, no. 3505, March 17, 1933, p. 312, and illustrations on p. 306, *d*)

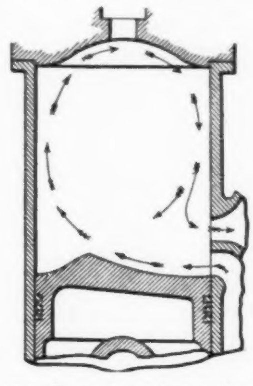


FIG. 9 SECTION THROUGH CYLINDER OF THE 7-HP TWO-STROKE AIRLESS-INJECTION ENGINE

MACHINE TOOLS

Continuous Planetary Precision Milling Machine

IT IS claimed that this machine makes possible a great speeding up of production precision milling, at the same time holding to the unusually close tolerances possible with planetary milling. The machine consists of six standard planetary milling heads mounted vertically about a large central supporting casting. The entire machine and the six heads revolve continuously about a central cam with six vertically running spindles milling the work. A vertical motor drives the entire machine through a large spur ring gear beneath the chip apron. The milling spindles are driven by individual vertically mounted motors through a silent chain drive.

In the continuous planetary, six machines have been built into one in order to reduce floor space and to make it possible for one man to operate all six. The machining principle embodied in this machine tool is well known and was described in the December, 1928, issue of *Machinery* (New York), but continuous planetary milling is claimed to have gone further in

pegging production at a predetermined rate by means of timing gears controlling the revolutions of the machine.

Individually motorized spindle drives to each head, independent milling-feed controls, and individual fixture throwouts enable the operator to throw the six units in and out of production as circumstances warrant. This precaution enables the other five heads to continue production in event of temporary failure or repairs to any one of them.

A departure from standard milling practice has made it possible to control the diameter milled in the work after cutters have been reground. This is done by using cutters in heads one to six consecutively and in between regrinding to specified sizes for each numbered head. This regrinding of the cutters to specified sizes eliminates shutdown to set to size.

Production is controlled by gears. Timed at 2 rpm of the entire machine, twelve pieces of work must be produced per minute. A production chart given in the original publication states, for example, that in thread-milling the nose of a shell $1^1/_2$ in. pitch diameter and $^3/_4$ in. long in chrome-nickel steel, the production was 6480 pieces in 9 hr. In form-milling the entire bore and ball grooves of a bearing race in chrome-molybdenum steel the production was 21,600 pieces in 9 hr. (Abstracted from a description submitted by the makers of the machine, The Hall Planetary Co. of Philadelphia, Pa., *d*)

MOTOR-CAR ENGINEERING

Distribution of Costs

BECAUSE of the scarcity of information on this subject the following is abstracted verbatim:

"Obviously, cost sheets are not made public, but the following is a fair breakdown for cars with an f.o.b. price of $500 to $600.

"The platform cost, which includes materials, parts, and labor for the completed car at the end of the assembly line is $105 to $125; in the case of a popular make, it is said to be $109 this year.

"The dealer's profit and salesman's commission absorb $150. For advertising the allotment per car is $25 to $30. One large corporation has appropriated $30 per car this season for radio, newspaper, and magazine advertising, dealer helps, and sales promotion. This manufacturer grants dealers local advertising, spent as the dealers direct, at the rate of $10 for each car sold. A truck manufacturer debits its dealers $10 for advertising for each small truck sold, and $20 for each large one.

"The difference, which is almost half the f.o.b. price, is overhead, zone supervision, profit, and other items. With production drastically curtailed, overhead per car manufactured has become an increasingly burdensome item.

"General Motors' report for 1932, for example, shows $592,694,766 set up for real estate, plant, and equipment, which averages almost $1300 on each of the 472,859 cars it sold to dealers last year. Attacking this problem vigorously, in 1932 it charged $37,173,647 against earnings for depreciation, and made a net decrease of $34,354,371 in its plant, real estate, and equipment account." (*Steel*, vol. 92, no. 16, April 17, 1933, p. 13, *g*)

POWER-PLANT ENGINEERING

A Heat-Extraction Engine

THIS engine is not suitable for central-station work but is recommended by the author for use where a combination of processes of heat and power is encountered. Either a single back-pressure or the compound heat-extraction engine can be used. The former, usually of single-cylinder design, is more suitable where there is a large and constant demand for steam and a comparatively small power load. The steam consumption of a back-pressure engine varies according to the initial and final steam conditions of pressure and temperature, but will usually lie between 17 and 21 lb per ihp-hr. The steam consumption of an engine taking steam at a pressure of 200 lb per sq in. (gage), superheated 200 F, and exhausting against a back pressure of 25 lb per sq in. (gage) will be about 20 lb per ihp-hr, and a 350-ihp engine will require, therefore, 7000 lb of steam per hr at full load as compared with 3460 lb per hr for a modern and efficient compound condensing engine having a uniflow low-pressure cylinder to enable a good vacuum to be attained in the engine cylinder at exhaust.

If the factory demand for steam at 25 lb pressure is exactly the same as the engine's demand, the combined scheme will require the generation of 7000 lb per hr of steam at 200 lb presure and 200 F superheat from feedwater at, say, 100 F, or a total heat demand of 8,753,500 Btu per hr as compared with a total of 12,055,000 Btu per hr with the scheme where power and heat are supplied from different sources. The combined scheme shows a saving of 27.4 per cent.

Should the demand for heating steam fall to half its previous value, the saving will be cut very materially. Therefore, for fluctuating steam and power demands, the overall economy of the simple back-pressure engine will be seriously impaired, and in such cases the heat-extraction engine may be used to advantage. In this type of engine the heating of process steam is drawn from the receiver from a combined engine, the pressure in the receiver being maintained constant.

If the demand for heating steam is large compared with the power load, the power is developed almost entirely by the passage of the heating steam through the high-pressure cylinder. Upon a reduction in the heating steam flow, a greater proportion of the steam passes also through the low-pressure cylinder to the condenser, thereby maintaining the output of the engine with a reduced total steam flow.

The installation can adjust itself economically to fluctuating demand for both heat and power and can furnish power at a very low cost under all normal conditions of load. The cost of such an engine is more than that of a plain compound condensing engine, but the reduction in the size of the boiler plant required will offset this and the operating economies achieved are said to be considerable.

To compare various types of equipment, the author assumes that the conditions for the "power" steam will be a gage pressure of 200 lb per sq in. and a superheat of 200 F, giving a total steam temperature of 588 F, with a 27-in. vacuum in the condenser. The heating steam will be saturated and is assumed to have a gage pressure of 25 lb per sq in.

From figures given in the original article it would appear that the extraction engine, when running as a normal compound condensing engine, is about 8 per cent less efficient than an engine designed for these conditions. Another table shows the total heat consumption of an extraction plant of different combinations of varying demand and varying power load, a boiler efficiency of 70 per cent being assumed.

From further data it appears that when an extraction engine supplies heating steam, an increasing power demand results in an increased credit to the extraction engine. An average figure for the economy of the combined scheme is 15 per cent.

The heat consumption necessary for power generation combined with heating steam is cited by the author with a view of determining the economies of private generation of electricity as compared with taking the public supply.

The supply of 3000 lb per hr of saturated steam at 25 lb per sq in. gage pressure will require 47.2 therms per hour in the coal (boiler efficiency = 70 per cent) while the combined supply of this quantity of heating steam together with a power load of 300 ihp will similarly require 92 therms per hour. Thus a power load of 300 ihp can be supplied with a heat consumption of 44.8 therms per hour. This is equivalent to a coal consumption of 1.27 lb per ihp-hr, or 1.95 lb per kwhr. (A. F. Webber in the *Fuel Economist*, vol. 8, no. 88, Jan., 1933, pp. 239–242, 2 figs., *pc*)

Elimination of Solid Matter From Flue Gases

THIS article is based on the recent report of the British Electricity Commission on the measures which have been taken in Great Britain and in other countries to obviate the emission of soot, ash, grit, and gritty particles from the chimneys of the electric power stations. The complete report is an extensive document. It considers several types of dust-extraction plants, dividing them into two distinct systems, wet and dry. The wet systems may be of several types; water film, water spray, and a combination of the two.

It is agreed that dust extraction can be satisfactorily carried out by means of a properly designed "wet" system. The sub-committee considers, however, that the use of water solely for the purpose of extracting dust is open to the following objections:

(1) Serious corrosion may occur unless special and costly precautions are taken, such as acid-proof lining of the chimneys and the protection of all iron and steel exposed to the wet gases.

(2) The possible difficulty of obtaining adequate supplies of water. It should be noted that salt water materially increases the risk of corrosion.

(3) The disposal or filtering of the effluent.

(4) The site area occupied by settling tanks.

(5) The necessity in some cases for neutralizing the recovered water before disposal.

(6) The cooling of the gases in the chimney causes loss of draft.

(7) With certain classes of coal, trouble may be encountered due to the caking and the building up of dust in the flues and extraction plant.

(8) The possibility that water particles will be emitted from the chimneys unless precautions are taken.

At the same time it is quite possible that where ample facilities exist as regards quantity of suitable water, and other conditions are favorable, a "wet" system may be justified.

The "dry" systems are divided into those of the cyclone type depending wholly upon centrifugal force and electric precipitators.

It is the considered opinion of the sub-committee that the single-cyclone-type extraction plant is reasonably efficient when dealing with dust above 40 microns, but that with dust below 40 microns its efficiency falls away to an extent that renders it unsuitable for use on pulverized-fuel-fired installations.

As regards electric precipitators, difficulty is often experienced in the disposal of the dust. At one station visited by the sub-committee the very fine dust caught by an electrostatic precipitator was drawn off from the hoppers of the precipitators into paper bags. (It is not stated what was done with the bags thereafter.) The plant in question was comparatively small.

The sub-committee investigated the question of capital and operating costs of various types of dust-extraction plants as well as such factors as the space occupied. A specification of the plant is set up based on one single boiler unit of approximately 200,000 lb of steam per hour or an output of roughly 20,000 kw, the plant to be erected in the London district. A detailed comparison of costs of various types of dust-extraction plants is given in Table 1 with the figures based on actual data given by the contractors. The figures for "dry" type do not allow for cost of dealing with the dust after leaving the dust-extraction-plant hoppers. (*The Steam Engineer*, vol. 2, no. 6, March, 1933, pp. 264–267, 4 figs., *c*)

Operating Experience With 1800-Lb Steam at Plant Carey

THIS plant is said to have the distinction of being the highest-pressure commercial plant in the United States and of containing the only reciprocating engines operating with steam at 1500-lb pressure and 780 F temperature. The plant has two cross-drum boilers, each rated at 150,000 lb per hr and generating steam at 1550 to 1750 lb per sq in. and 780 F.

Each boiler is fired by four tangential burners and is served by four pulverizer mills having a capacity of 1.8 ton per hr. The furnaces are surrounded by fin-tube water walls and have dry bottoms of stepped design to facilitate disposal of ash through a sluicing trough at the rear of the boilers.

The two 3750-kw vertical triple-expansion engines, operating at 225 rpm, receive steam at 1500 lb and exhaust it to evaporators at 65 lb. These units were designed for a throttle pressure of 100 kg per sq cm (1422 lb per sq in.) and a steam temperature of 425 C (797 F). The normal operating pressure, however, is approximately 1500 lb. This pressure is reduced at very low loads and is occasionally increased to 1600 or 1650 lb at full load when necessary to balance the supply of exhaust with the demand for process steam. Each engine has two high-pressure cylinders, single-acting, $14^1/_2$ in. in diameter, two intermediate cylinders, single-acting, $21^1/_4$ in. in diameter, and one low-pressure cylinder, double-acting, $25^5/_8$ in. in diameter. The high-pressure cylinders are above the intermediates.

The two high-pressure pistons operate downward and the two intermediates operate upward on the same piston rods, so that the engines have only three cranks. Steam from the intermediate cylinders is reheated to 526 F in live-steam reheaters located at the engine before going to the low-pressure cylinders.

Exhaust steam at 65 lb from the main engines and from the engine-driven feed pump is condensed in two evaporators of

TABLE 1 COMPARISON OF COST, ETC., BETWEEN VARIOUS TYPES OF DUST-EXTRACTION PLANT

Type of plant	Capital cost, £	Capital charges, £	Operating cost, £	Maintenance cost, £	Draft loss, £	Total cost per annum, £	Space occupied (approx.) Sq ft	Space occupied (approx.) Cu ft	Draft loss, in.	Outlet temp., F
Water film (with settling tanks)	3358	336	123	100	151	710	2440	14,880	0.75	120
Water film (with filter plant)	6308	631	442	200	151	1424	1480	23,190	0.75	120
Combined water spray and film (with settling tanks)	3450	345	123	100	201	769	3010	25,338	1	140
Combined water spray and film (with filter plant)	6400	640	442	200	201	1483	2050	33,648	1	140
Electrostatic	6000	600	190	50	50	900	980	41,000	0.25	250
Multi-Cyclone	3420	342	75	60	395	873	900	46,200	2	250

150,000 lb per hr capacity which supply steam at 45 lb to processes in the manufacturing plant. The exhaust steam passes through an oil separator between the engine exhaust and the evaporator coils. A third evaporator receives condensate trapped from the live-steam reheater and from the separator in the main steam line and also is supplied with live steam through a reducing valve. Water to the evaporators is treated in a hot-process softener.

A number of operating difficulties were experienced but the majority of them have been mastered. The first and most serious difficulty was that the two machines could not be synchronized with each other or with the gasoline-engine-driven unit which was installed for starting and standby service. This difficulty was removed by the addition of a flywheel and the installation of compensating coils in the generator winding. Difficulty was also experienced with the lubrication of the high-pressure cylinders, and the original article tells how this problem was solved.

In the boiler room much trouble was caused at first by the formation of slag on the water-wall and screen tubes. This has since been eliminated by the installation of larger burner tips and right- and left-hand deflector plates, as well as by better air regulation. The control of scale from feedwater, the picking up of cylinder oil by steam passing through the engines, etc., had to be mastered. Incidentally, analyses of the feedwater at various points in the system disclosed the fact that the feedwater increased in hardness in passing through the oil-removal filter. In part this hardness came from the filter material which was being dissolved by the condensate. This filter material was crushed dolomite rock and gravel with an upper layer of silica sand. The condition was corrected by replacing the filtering material with magnetite ore.

The superheaters at first did not produce the superheat for which the engines were designed and for the first year of operation the average steam temperature was about 700 F. Then the baffles were rearranged and with certain other changes the average operating temperature was brought up to 780 F without apparently any adverse effect on lubrication or wear of the engine cylinders, but with the decrease in steam rate.

In operation it has been found that the reciprocating steam engine can produce more by-product power from small quantities of steam than any turbine which has yet been designed. The practicability of this type of prime mover for high steam pressures has been definitely demonstrated.

A caption in an illustration in the original says that because the main engines were made in Germany, spare crankshafts and connecting rods are kept available. (H. P. Stephenson, Power Engineer, The Philip Carey Co., in *Power*, vol. 77, no. 5, April, 1933, pp. 169–172, illustrated, *d*)

Plywood

(Continued from page 357)

structural strength—plywood is superior to shiplap for sheathing. The saving in labor may amount to as much as 50 per cent. As the strength of this material is approximately the same in both directions, plywood sheathing provides greater rigidity than diagonal bracing. One-half-inch 5-ply unsanded plywood may be used successfully as sheathing when special-width door and window jambs are specified. When standard-width jambs are specified, $^3/_4$-in. unsanded plywood is recommended. For the best results plywood sheathing should be rabbeted or shiplapped on the edges which run at right angles to the studding. The plywood need not be covered with felt or waterproof paper, although it is recommended that boiled linseed oil be brushed or sprayed on the outside and that the edges and joints be sealed with emulsified asphalt or paint.

PLYWOOD AT THE CENTURY OF PROGRESS EXPOSITION

The Hall of Science at the Chicago Century of Progress Exposition is a huge structure 700 by 400 ft, the walls and decking of which are made of plywood. This building is in the shape of a "U," and encloses on three sides a court capable of accommodating 80,000 persons. At one corner rises a 176-ft tower equipped with a carillon.

The Hall of Science required approximately 300,000 sq ft of plywood as all of the vertical exterior surfaces of this building are made of plywood. Five-ply panels, sound on both sides and sanded two sides to $^1/_2$-in., were used on all flat areas. On curved areas two $^1/_4$-in. panels were used, one over the other and slightly staggered to form lap joints at the edges. The $^1/_4$-in. panels were thin enough to bend on any of the radii in this building without being steamed or saw cut on the back, and by using two $^1/_4$-in. panels the wall thickness on the curved areas was built up to equal that of the flat areas where a $^1/_2$-in. panel was used. (See Fig. 5.)

One of the major labor-saving features, and a feature also which insures accurate work, is the fact that practically all the plywood used in the buildings was machined at the factory and each piece numbered. The wall panels were cut to specified shapes and sizes at the mill, and on the job they are nailed, screwed, or clipped to wood or metal studs supported on the steel framing or held in place without nails in metal runners secured to the wood or metal studs.

In addition to the 300,000 ft of $^1/_2$-in. plywood used for the exterior walls of the Hall of Science, 800,000 ft of $^5/_8$-in. tongue-and-grooved plywood was used for sub-flooring on interior decks and roofs and terraces in this and other large buildings at the Exposition.

A.S.M.E. Boiler Code

Revisions and Addenda to the Boiler Construction Code

IT IS THE policy of the Boiler Code Committee to receive and consider as promptly as possible any desired revision of the Rules and its Codes. Any suggestions for revisions or modifications that are approved by the Committee will be recommended for addenda to the Code, to be included later in the proper place in the Code.

The following proposed revisions have been approved for publication as addenda to the Code. They are published below with the corresponding paragraph numbers to identify their locations in the various sections of the Code, and are submitted for criticism and approval from any one interested therein. Communications should be addressed to the Secretary of the Boiler Code Committee, 29 West 39th St., New York, N. Y., in order that they may be presented to the Committee for consideration.

PAR. I-60. ADD THE FOLLOWING SECTION:

Form A[1] shall be used upon the first internal inspection of any boiler by all inspectors and thereafter forms B[1] and C[1] should be used for all inspections, unless changes or repairs warrant the filing of a new form A[1] report.

[1] Copies of these forms for examination may be obtained upon application to Secretary, Boiler Code Committee, A.S.M.E., 29 W. 39th St., New York, N. Y.

CORRESPONDENCE

READERS are asked to make the fullest use of this department of "Mechanical Engineering." Contributions particularly welcomed at all times are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on its activities or policies in Research and Standardization.

Unemployment and Patent Monopoly

To the Editor:

Experience proves that spectacular advances of science which effect material reductions in the cost of established products tend toward a social upheaval.

Concurrent with the cost reductions, men are thrown out of employment. Then the gradual broadening of the market resulting from a lower price may result in some measure of reemployment, but the general trend established by the replacement of men with machines, in an established industry, is inevitably toward the employment of a smaller number of men, with a reduced total payroll. When this trend has progressed to a degree which, in combination with other trends, is critical, the social machine is thrown out of gear, and sooner or later it becomes necessary to reduce the length of the working day. Recourse to this remedy is delayed as long as possible, because it is impractical for most individual concerns to meet competition if they act alone to shorten their own working day while competitors maintain the old standard hours of work. It also seems to be impractical for a whole industry to shorten the working day of all the individual firms through friendly agreement. Only during a national crisis has it been possible to drive home the conviction that national prosperity demands that Mr. Common People have money to spend, and be warranted in spending it, because of steady employment.

We now believe that we are on the upgrade from the depths of a very bad depression. Many active minds have had a long period of freedom from the continual demands of going business during this period. We must face the cold fact that new processes have been conceived by these minds, and will be reduced to practice to retrieve losses and regain position. As business approaches a normal volume, these new processes may escape the appearance of causing unemployment, but they will inevitably limit reemployment to a volume lower than would have existed under a like resumption of business, predicated upon the older processes.

When in an established business a new process is launched which effects a saving in labor great enough to be in itself a potential disturbance of the social order, there is a practical manner of minimizing the disturbance, if the process is covered by valid patents. If the process is sufficiently revolutionary to menace the social order, competitive firms will negotiate for the right to operate under license. Under these conditions the rights of labor and the welfare of the social machine can be safeguarded by including in the license agreement stipulations limiting the maximum number of hours in a working day and defining rates of pay which will make an equitable division of the savings resident in the process between the three interested parties—namely, labor, invested capital, and the consuming trade. These stipulations may well be made to apply for a limited time to smooth over the period of readjustment.

The determination of this equitable distribution is a delicate and difficult task. We have repeatedly seen situations where an engineer, having conceived a new idea, used the reduction of cost as the major argument for selling to his management the adoption of his scheme. But repeatedly the saving failed to materialize to his employers directly, because under the drive of competition it seemed necessary to hand the savings over bodily to the customer to secure business. This is not an equitable division of cost reduction.

The continual yielding to the pressure to make this inequitable distribution is a very serious error, because sooner or later it reduces the amount of money which labor has to spend, and the well-known vicious cycle of depression is started. There is therefore ample incentive for management to keep a sharp lookout for opportunities to forestall this cycle, and the broad power granted by the law in the control of business conducted under patent license offers one way in which technological unemployment can be controlled in some measure. This incentive should be adequate, if management has only the most cold-blooded interest in self-preservation. But any management having sufficient courage to follow the suggested course will gain as a by-product a very wonderful advertising value, as well as the satisfying of any humanitarian interest which it may be fortunate enough to possess.

George M. Eaton.[1]

Ambridge, Pa.

Public Works and Recovery

To the Editor:

In Mr. J. Billeter's letter in the January issue of Mechanical Engineering, under the title "Public Works and Recovery," the thesis therein set up reminds me of the comment of a friend as to the contractor's profit on a $90,000 highway. "The contractor," remarked this friend, "must have made a pile of money on this job. His labor didn't cost him over $6000. He told me so himself." "And the remainder was profit?" "Certainly. What else could it be?" "Perhaps," I countered, "but, what about the materials?" "Oh," he replied, "I hadn't thought of them." Several other things had been overlooked, and in fact the contractor had not made a cent on that job.

When the effect of public works on employment is under consideration, it is not unusual to find that many things are being overlooked. Some of the labor is in plain sight. In highway construction the amount of this labor varies greatly. About 15 per cent of the cost of laying a concrete slab is paid to the labor used on or about the job. On the average grading job nearly 50 per cent of the cost goes to the labor employed. For a large highway program the average is a little over 25 per cent.

[1] Director of Research, Spang-Chalfant & Co., Inc. Mem. A.S.M.E.

But besides the labor used on the job, highway construction, in common with all other types of construction work, involves much work that must be done in other places. During 1932, 50 per cent of the cement produced in this country went into new state-highway mileage. Very little of this cement came from stock. Practically all that was used meant labor at the cement mills.

Nearly 70 per cent of the gravel and stone handled last year was produced for highway purposes, as was about 50 per cent of the sand. Though not so plainly in sight, these items are just as effective in providing labor as is the work done on the job, for the producers of these materials carry no stocks of consequence. Rehandling charges prevent their doing so.

It is not necessary to comment on the other materials used in quantity in highway construction or on the considerable amount of machinery and hauling equipment built every year for use in the highway field, in order to make it clear that the visible employment on this work is only a fraction of the total employment involved.

Even on the railroads the volume of business handled, and with it the volume of employment, is affected by activity in the construction field. For instance, during 1932 the railroads appear to have obtained not far from 60,000,000 tons of revenue freight from state-highway construction. This is not far from 10 per cent of their total volume of business—by no means a negligible influence on employment.

When all of the money paid out for construction work is traced back in an analysis of the things it buys and when the labor that these things generate is determined, it will usually be found that not far from 90 per cent of the money spent on construction work is ultimately paid in wages and salaries. In the highway-construction field somewhat more than this percentage now reaches labor, for profits all along the line are low or are non-existent.

The current depression is at least largely a construction depression. We are not building in any field at the rate that prevailed during the last decade. The result is that millions of men who were then employed are now unemployed. Public works as well as all types of private construction work are of peculiar value at this time because they tend to correct the primary difficulty we are now facing—unemployment in the construction field and in those industries that exist for the purpose of serving construction. If normal activity could be redeveloped here, our economic structure would right itself without much trouble.

J. L. HARRISON.[2]

Washington, D. C.

Training the Engineer to Think

TO THE EDITOR:

Prof. R. E. Doherty's paper, "Educational Preparation for Creative Technical Engineering Leadership," in the February issue of MECHANICAL ENGINEERING, prompts me to some observations, of which only a part are pertinent to his treatment of the subject. His thesis is essentially as follows:

(1) There is a deficiency in the qualities which make for leadership among those engaged in engineering activities.

(2) This deficiency is attributable to lack of the power of independent thinking.

(3) The want of thinking ability is in its turn ascribed to overloading the mind with useless (?) facts.

(4) This situation can be corrected by the simple expedient of decreasing the amount of factual knowledge which the student must acquire and devoting the time thus saved to instruction in *thinking*.

[2] Bureau of Public Roads, U. S. Department of Agriculture.

He says: "The colleges have graduated too many engineering technicians and too few creative thinkers." The proper reply to this statement is that it is not the business of the college authorities to determine whether or not there are too many engineering technicians; so long as they maintain technical schools it is their business to train a student for technical engineering if technical engineering is what the student wants.

Engineering for upward of 95 per cent of its practitioners is a trade. The facts, figures, formulas, tables, manipulatory skill, etc., of which Professor Doherty speaks almost sneeringly are the tools of that trade. The prospective employer expects the young engineer to possess a full set of those tools and to be able to use them; without them the young man will not hold a job, even if he should become so fortunate as to get one.

Engineering is not an end in itself; it is a part of the business machine. Its value is measured in dollars and cents, and it must justify itself on that basis. There is an apparent exception to this in the case of research organizations, but it is only apparent; financial results are not expected immediately, but they must materialize eventually or the research organization will cease to exist.

Professor Doherty proposes to train students to *think*. The idea is not new; it has been, as far back as my memory goes, the avowed purpose of all educators, and it is fair to assume that they have always exerted their best efforts toward that end.

In order to find time for this special instruction, he suggests the elimination of some of the "facts and figures" with which students "gorge their memories" and which he looks upon as excess baggage.

In whatever degree the student's stock of "technical engineering minutiæ" may be diminished, by just that much is he handicapped in his struggle to hold a position in the engineering business world. The man who knows too much is a *rara avis*, and most of us find ourselves frequently embarrassed by our ignorance of something we are expected to know, no matter how diligently we may have studied in the past or how large a stock of engineering details we may have accumulated.

There is another phase to the suggestion that the student learn fewer facts in order that he may have more time to think. The more time he is given for thinking, the less does he learn about which he may think. No amount of thinking can create much out of a small stock of facts and figures. Goethe said that "a vast abundance of objects must lie before us ere we can think upon them." This is as true in the restricted field of engineering activity as in the world contemplated by Goethe.

I once knew a professor of philosophy who used to say in his lectures that it was the business of the scientist to observe, to amass facts—the business of the philosopher to think about them. That idea (if, indeed, it could be called an idea) is now as extinct as the dodo. The only man whose thinking on any set of facts can be productive is one to whom those facts are significant and alive. Academic contemplation of things which do not touch the thinker's life is sterile.

Professor Doherty proposes to limit his instruction in thinking to a selected group—to create a sort of aristocracy of *thinking*, as distinguished from the *working* engineers. Those selected will of course be the "best students"—i.e., those whose reaction to a mental stimulus is conventional, whose performance conforms to the preconceived standards of the instructors, who always respond with the "answer in the book." This will insure the choice of mediocrity, the elimi-

nation of all originality and independence, for the group of super-engineers to whom the ordinary man, charged with the responsibility of getting things done, is to look up with reverence and awe.

I venture to assert that no man can be taught to think. The most that can be done is illustrated by the story of a negro who, when drafted for the army, protested that "Uncle Sam can't make me fight." To this his friend replied, "Well, Rastus, perhaps Uncle Sam can't make you fight, but he can take you and put you where the fighting is, and then you can use your own judgment."

Similarly, I suggest that engineering students be taught as much as possible of the underlying sciences, together with all the facts, figures, and formulas their minds will hold, and that then they be put "where the thinking is." Out of the hurly-burly the creative thinkers will emerge by the process of natural selection.

Professor Doherty speaks of "leadership" and of "creative thinking" indiscriminately. They are in no sense the same thing; on the contrary, they are in considerable degree antithetic. Whatever else may be said of the leaders who, in all ages, have been most influential in directing the trend of human affairs, few of them have been profound thinkers. History is replete with examples.

On the other hand, many of the ablest and most scholarly thinkers in all lines of intellectual activity have lacked any trace of the quality of leadership. Often their influence has not been evident until a generation or more after their death. This is natural. The real thinker, as distinguished from the publicity-seeking pedant, of necessity is pretty much of a recluse. Contact with the general run of people disturbs and interrupts his mental operations; he is influenced by what the chemist calls "mass reaction." Leaders and thinkers, widely different as they are, have, however, one feature in common—neither can be made to order.

There is one other point which seems appropriate here, although it is not strictly germane to Professor Doherty's paper. It has become increasingly the vogue to urge that engineers are especially qualified for leadership in all sorts of human affairs, though no one has satisfactorily explained why it should be so. There seems to be no basis for this, except a false class pride. Engineers come from all walks of life, from all strata of society. They have no common background—social, moral, or intellectual. They are a heterogeneous assortment of men who have been trained for the same field of business activity. It is probably not possible to characterize them as a class, but if I were to attempt to do so, I should say that they are by nature no more and by training far less qualified for leadership than most other classes of trained men.

This is rank heresy, but its justification is fairly obvious. By far the larger part of engineering training has to do with inanimate forces and things. The engineer is accustomed to laws and reactions which are the same yesterday, today, and tomorrow. He is concerned only in a minor degree with the whims, fads, fancies, and emotional irresponsibilities of the (more or less) human race; hence he finds himself on unfamiliar ground when he comes to deal with human relationships and, more likely than not, makes a mess of it.

This is not to say that there have been no great leaders in the engineering ranks. There have been, of course, but those men became leaders not because they were engineers but in spite of it.

It is time we dropped the childish pretense that we are a superior class of beings, better qualified than any one else to run the world's affairs. We can take a proper pride in our contributions to civilization without making the silly claim that we created the whole social structure. The carburetor is an important part of the automobile, but it could not travel many miles per hour without a lot of cooperation from other parts of the machine. We are a part of life's merry-go-round, but we do not make it go. We should drop the pose of the fly which sat on the wheel hub during the chariot race and exclaimed, "Great Pluto! What a dust I am raising."

CHARLES W. COMSTOCK.[3]

New York, N. Y.

The Fermi-Dirac Statistical Theory of Gas Degeneration—III

(Continued from page 362)

where k is some universal constant. The entropies are added when the probabilities are multiplied. Equation [50] gives

$$\Sigma s_i = k \Sigma \log p_i = k \log (\Pi p_i) \quad [51]$$

so that

$$S = k \log p_{t_{max}} + \text{Const} \quad [52]$$

A constant is added because in classical thermodynamics (as distinct from some modern forms of statistical mechanics) the entropy of an aggregate can be known only to an additive constant. The intermediate constant is eliminated on the basis of the Nernst-Planck heat theorem (the third law of thermodynamics). $p_{t_{max}}$ is used in place of p_t because the entropy of the actual stable condition of gas is meant. This condition is the most probable state or, more accurately, an average state almost indistinguishable from it.

By considering the actual Maxwellian distribution of velocities among the molecules of a gas, the most probable distribution may be found using a straightforward mathematical method. The result for the entropy of a non-degenerate gas is of the form

$$S = kN_0 \log (T^{1.5}V) + \text{Const} \quad [53]$$

where N_0 is the number of molecules per gram-molecule. Differentiating Equation [53],

$$dS = 1.5kN_0dT/T + kN_0dV/V \quad [54]$$

Comparing expressions [46] and [54], it is found that

$$c_v = 1.5kN_0 \quad [55]$$

$$R = kN_0 \quad [56]$$

From these equations

$$k = R/N_0 \quad [57]$$

$$R = c_v/1.5 \quad [58]$$

Thus, knowing the specific heat of a gas at constant volume, the universal gas constant R may be computed from Equation [58] and then k determined from Equation [57].

While any value of k will do in Equation [52], so long as only entropy and probabilities of state are dealt with, this constant must have the particular value given by Equation [57], in order to agree with thermodynamic changes in the gas as a whole.

The universal constant R is quite well known among the physicists and engineers, and it may now be stated that the constant k is equal to R per molecule of gas.

[3] Mem. A.S.M.E.

BOOK REVIEWS

THE Library is a cooperative activity of the A.S.C.E., the A.I.M.E., the A.S.M.E., and the A.I.E.E. It is administered by the United Engineering Trustees, Inc., as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets, and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West 39th St., New York, N. Y. In order to place its resources at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references on engineering subjects, copies of translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

Heat Transmission

Heat Transmission. By William H. McAdams. McGraw-Hill Book Company, Inc., New York, 1933. Cloth, $5^3/_4 \times 9$ in., 383 pp., 135 figs., $5.

Reviewed by Wm. L. De Baufre[1]

THIS book is sponsored by the Committee on Heat Transmission of the National Research Council, the author being chairman of the Subcommittee on Heat Transfer by Convection.

The book deals with conduction, radiation, and convection of heat. Convection is most thoroughly covered, about two-thirds of the book being devoted to this phase of heat transmission. Fundamental physical conditions are described, recent experimental data are given, and these data are analyzed to determine the best relations for engineering practice. Radiation is discussed in a more superficial manner, particularly with respect to the discussion of the fundamental physical conditions for radiation from the constituents of non-luminous gases. The bibliography at the end of the book, however, will enable the student to carry his studies further if he desires a better understanding of this phase of the subject.

Thermal conduction through a single homogeneous solid is treated in Chapter I, four typical cases being discussed. The first case deals with conduction of heat through a solid of constant cross-section, such as a flat wall or a well-insulated furnace electrode. In the second case, the cross-section of the path of heat flow is proportional to a linear dimension, as in radial heat flow through lagging around cylindrical pipes. The third case deals with the less usual situation where the cross-section of the path is proportional to the square of a linear dimension, as in radial heat flow through material between concentric spheres. The fourth case covers heat flow through the walls of rectangular inclosures having walls at least one-half as thick as the shortest inside dimension.

Thermal conductivity of liquids and of gases is also discussed in Chapter I. This is followed by heat conduction through several bodies in series, using the resistance concept, and by heat conduction through several bodies in parallel. Contact resistance is discussed in connection with bodies in series. Heating and cooling bodies, including slabs, cylinders, spheres, and semi-infinite rods, are treated in Chapter II.

Chapter III deals with radiation of heat. Radiation between solids is first discussed for the case where the surfaces of the solids are separated by a non-absorbing medium. Data on emissivity for various surfaces and factors for different shapes are included. The method of calculating radiation from water vapor, carbon dioxide, and sulphur dioxide in non-luminous gases is described, families of curves being given for this purpose. Radiation from clouds of particles, including powdered-coal flames, is next discussed. The chapter ends with a discussion of the general problem of the combustion chamber with heat-absorbing and refractory surfaces.

The remainder of the book deals with convection of heat. As a foundation for this study, dimensional analysis is described in Chapter IV, and the flow of fluids is discussed in Chapter V. The latter deals with pressure losses due to fluid friction as affected by streamline and turbulent motion, by shape and roughness of pipes, and by heat transfer, for flow outside as well as inside pipes. Flow through packed tubes and enlargement and contraction losses are also treated.

In the introduction to convection in Chapter VI, the temperature gradient from a fluid being cooled through an intervening wall to a fluid being heated is first described as a basis for determining the relation between the overall coefficient of heat transfer and the individual coefficients for the fluid films, metal wall, scale, etc. The average temperature of the fluid and the mean temperature difference are discussed.

Convection heat transfer for fluids flowing inside pipes is very thoroughly treated in Chapter VII for both turbulent and streamline flow. Data from many sources are plotted in accordance with dimensional analysis for both heating and cooling water, steam, air, oil, and other fluids. For turbulent flow of all these fluids, a single general relation is derived. This general relation is simplified for gases and for superheated steam.

Convection heat transfer for fluids flowing outside pipes is treated in Chapter VIII. Data are plotted for air, water, and oil flowing at right angles to a single cylinder and through tube banks, and general relations are derived. Natural as well as forced convection is included, and flow through annular spaces and the effect of fins are discussed.

Heat transfer from condensing vapors is the subject of Chapter IX, and heat transfer to evaporating liquids is the subject of Chapter X. The mechanism of condensation and of evaporation is discussed, data from various sources are plotted, and relations are derived for design purposes.

Numerical data are given in an appendix on thermal conductivities of metals, certain alloys, building and insulating materials, liquids, gases, and vapors; specific heats of certain solids, liquids, and gases; and viscosities of water and of certain liquids and gases. This appendix is followed by a bibliography and author index of over four hundred references.

As stated in the preface, the book is designed to serve both as

[1] Chairman, Department of Applied Mechanics and Engineering Drawing, The University of Nebraska, Lincoln, Neb. Mem. A.S.M.E.

a text for students and as a reference for practicing engineers. Also, the stated purpose is to present fundamentals rather than to deal with details of individual problems and special cases encountered in various industries. Although some of these fundamentals have been known for a number of years, it is only recently that they have replaced the rough approximations so often used in heat-transmission calculations. The necessity for greater accuracy has required engineering designers to look at their problems with a better understanding of the fundamentals involved. This book brings to designers the latest experimental data and most of the fundamental viewpoints in heat transmission. It will also enable educators to present a more thorough course in this subject to engineering students.

The book is very well written and represents a tremendous amount of work in correlating data and in preparing tables, curves, etc. The sponsors and publishers as well as the author are to be congratulated in making such a noteworthy contribution to the literature on heat transmission.

WHAT'S GOING ON

Candidates for Membership in the A.S.M.E.

THE application of each of the candidates listed below is to be voted on after June 24, 1933, provided no objection thereto is made before that date, and provided satisfactory replies have been received from the required number of references. Any member having comments or objections should write to the Secretary of the A.S.M.E. at once.

NEW APPLICATIONS

ARONOWSKY, SAMUEL, Brooklyn, N. Y.
ATSUMI, JOHN S., Stockton, Calif.
AUSTIN, WILLIAM H., Hyde Park, Mass.
BARKS, GEORGE T., Northampton, Mass.
BARNES, M. H., McComb, Miss.
BAYLOR, J. EDWARD, Canton, Ill.
BELMONT, ROBERT I., Middleboro, Mass.
BERNITT, Elmer W., Detroit, Mich.
BILTY, C. H., Milwaukee, Wis.
BLANCKENBURG, EMIL, San Francisco, Calif.
BORKOWSKI, JOHN, Amsterdam, N. Y.
CAGNONI, GUIDO J., Kenvil, N. J.
CAMERON, GEO. C., Washington, D. C.
CARLSON, ALBERT R., Brooklyn, N. Y.
CHILDS, E. WALLACE, Providence, R. I.
CHRISTENSEN, C. H., Astoria, L. I., N. Y.
COOK, WARREN G., Warrenton, Oregon
COOKE, RICHARD W., JR., Ridgewood, N. J.
CRATER, MYRON L., Pasadena, Calif.
DAME, FRANK E., Forest Hills, L. I.
DANNEMANN, HENRY F., JR., New York, N. Y.
DAVIS, F. R., San Diego, Calif.
DAVIS, JOHN MARC, Oklahoma City, Okla.
FINNERTY, JOHN A., Roslindale, Mass.
FOSTER, WILLARD H., West Roxbury, Mass.
FRANK, MAX, New York, N. Y.
GRAHAM, W. M., Chicago, Ill.
HAHN, RAYMOND P., Kansas City, Mo.
HILLIARD, ALTON M., Claremont, N. H.
HODGES, KENNETH R., Iowa City, Iowa
HOWE, LYLE F., Marshalltown, Iowa
INGHAM, WILLIAM A., Oakland, Calif.
KEIRN, AMOS H., Cresson, Pa.
KENT, Norman W., Ridgefield Park, N. J.
KEYS, L. F., New York, N. Y.
KLEIST, DALE, Columbus, Ohio
KLISE, ROBERT E., East Grand Rapids, Mich.
KOWALSKI, EDWARD, Passaic, N. J.
KRAUSE, FLOYD CARL, Akron, Ohio
LIPP, JAMES E., Los Angeles, Calif.
LUBBE, WILHELM, Vereeniging, S. Africa
LUCKEY, D. F., JR., Columbia, Mo.
LYONS, WM. T., New Rochelle, N. Y.
MANGELS, HERBERT E., St. Albans, L. I., N. Y.
MATUKAS, JOHN J., Readville, Mass.
MAURICETTE, ROBERT E., Dover, N. H.
MCKEAN, MILTON I., Troy, Pa.
MCQUINN, ALBERT O., Pittsburgh, Pa.
PARMESAN, DANIEL J., Houston, Tex.
PATTERSON, FRANCIS, New York, N. Y.
PAVLIK, FRANK L., Philadelphia, Pa.
PEIRCE, CHARLES H., Arlington, Mass.
PEPOON, PHILIP W., Waverly, Nebr.
PIPPEL, D. C., Grand Haven, Mich.
POWELL, J. LEWIS, Philadelphia, Pa.
PRITCHARD, R. H., Ossining, N. Y. (Rt. & T.)
PURCELL, JOHN, Chicago, Ill.
ROGERS, JAMES C., Hempstead, L. I., N. Y.
RUSCH, KENNETH A., Milwaukee, Wis.
SABLACAN, FRED W., Detroit, Mich.
SCHAEFER, JOHN F., Milwaukee, Wis.
SCHNEIDER, PHILIP JOSEPH, Roosevelt, L. I., N. Y.
SHEPARD, EDWARD C., New York, N. Y.
SMEAL, MALDINE W., Akron, Ohio
SNYDER, HARRY P., Lorain, Ohio
STANLEY, C. MAXWELL, Muscatine, Iowa
STEEN, HERBERT M., New York, N. Y.
STROSS, CHARLES H., Whiting, Ind.
TURLEY, WILLIAM D., Moberly, Mo.
UPTON, EDWARD WM., San Francisco, Calif.
VANT, ISADORE, Denver, Colo.
VON WEHRDEN, F. WALTER, St. Louis, Mo.
WILKINS, ARTHUR C., Cliftondale, Mass.
WINBOLT, L. W., Wheaton, Ill.
WOODS, CLINTON D., Pullman, Wash.
WYNN, FRANK C., Bartlesville, Okla.
YATES, RICHARD C., Cincinnati, Ohio
ZOLLINGER, JOHN J., Old Bridge, N. J.

CHANGE OF GRADING

Transfers from Associate-Member

BOYLES, ROBERT M., St. Louis, Mo.
EWART, W. M., St. Louis, Mo.
HIEBELER, HARRY G., Houston, Tex.
HIGGINBOTHAM, OSCAR, Perico, Cuba
ROBERTSON, J. D., North Dighton, Mass.

Transfers from Junior

GEIGER, J. W., West Lafayette, Ind.
GILBERT, RUSSELL L., London, Ontario, Canada
GORDON, EUGENE, Hagerstown, Md.
GOW, RALPH F., Paris, France
GUBA, HENRY ARTHUR, Waltham, Mass.
HALL, WILLIAM S., Ridgefield Park, N. J.
HEINTZE, ARTHUR L., St. Louis, Mo.
HOLMES, CLAYTON W., Haverford, Pa.
KING, KENNETH J., Philadelphia, Pa.
LINDELL, W. FRANCIS, Newark, Del.
NEEDS, SYDNEY J., Philadelphia, Pa.
OGAWA, YOSHIO, Los Angeles, Calif.
WALLIN, JOSEPH W., South Williamsport, Pa.

Transfer from Student Member

GOODALE, FRANCIS, New York, N. Y.

Chicago Power Show Plans Changed

PLANS for the Sixth Mid-West Engineering and Power Exposition, announced in previous issues of MECHANICAL ENGINEERING have been changed. The Power Show will be held at the Stevens Hotel, instead of the Coliseum as originally planned, and will be open for three consecutive days, commencing Tuesday, June 27.

Nominations for Awards

MEMBERS of The American Society of Mechanical Engineers are entitled to make nominations to the Committee on Awards regarding the following:

1 The Holley Medal for some act of genius of an engineering nature that has accomplished a great, timely public benefit.

2 The A.S.M.E. Medal for distinguished service in engineering and science.

Any member of the Society presenting the name of an engineer for the award of this medal shall forward a full statement of the grounds upon which the award might be expected, such statement to be published in MECHANICAL ENGINEERING. The attainments for which the nomination is made must be described in MECHANICAL ENGINEERING thirty days before the Committee on Awards considers the recommendation of the award to the Council, and the Council must approve the nomination by at least a two-thirds vote.

3 The Melville Medal to be presented for an original paper or thesis of exceptional merit presented to the Society for discussion and publication.

4 A Junior Award for the best paper submitted by a Junior Member.

Nominations for awards to be made for the current year should be in the hands of the Committee by July 15, 1933, and should be addressed to the Secretary, A.S.M.E., 29 West 39th Street, New York, N. Y.

ENGINEERING WEEK

at Chicago, June 25-July 1

THE 1933 Semi-Annual Meeting of The American Society of Mechanical Engineers, to be held in Chicago, Ill., during Engineers' Week, June 25 to July 1, in connection with the Century of Progress Exposition, promises to be one of the largest and most interesting gatherings that the Society has ever held.

Meeting in Chicago during this same week will be upward of 15 engineering, scientific, and technical societies, including the four Founder Societies, with many of which joint sessions have been scheduled. The A.S.M.E. Professional Divisions have concentrated their numerous national meetings at Chicago this year, and hence the technical program of the A.S.M.E. is extensive and varied. Moreover, the Century of Progress Exposition will attract hundreds of engineers to Chicago, and the Sixth Mid-West Engineering and Power Exposition, to be held at the Stevens Hotel, June 27 to 29, inclusive, will stimulate further interest. Railroad rates have been reduced, an additional incentive to draw large numbers to this important meeting. General information on special railroad rates will be found elsewhere on this page.

The Palmer House has been designated the official headquarters of the A.S.M.E. It will be the scene of the technical sessions and of many of the non-technical events. Arrangements have been made so that A.S.M.E. members who notify the hotel authorities of their coming will have accommodations reserved for them.

THE PROGRAM

On the following pages will be found the A.S.M.E. program of technical sessions and non-technical events in as much detail as is possible at this time. In general, events center about Engineers' Day, Wednesday, June 28. The program for the other days consists of technical sessions which commence at 9:30 a.m., a luncheon at 12:15 p.m. at which some eminent engineer or scientist will speak, plant visits commencing at 2 p.m., and other technical sessions at 2:15 p.m. A variety of entertainment, both technical and non-technical in nature, is provided for the evenings. Joint meetings with other societies are noted in the program.

Meetings of technical and other A.S.M.E. committees will be announced later.

Such activities for the women as have been definitely planned at this time will be found in the program of non-technical events.

Programs of the other engineering societies meeting during Engineering Week will be available at Chicago. In most cases, members of the A.S.M.E. are invited to attend such sessions of these societies as may interest them. For a majority of these, no registration fees will be charged.

The program for Engineers' Day, in which all of the engineering societies will participate, will include the presentation of the Guggenheim Award to Juan de la Cierva, inventor of the autogiro, which will take place at Soldier Field, in the Exposition grounds, with colorful and appropriate ceremonies. Engineers' Day also affords the opportunity for an official inspection of the Exposition and the many exhibits that will be of especial interest to engineers. Luncheon may be had on the Exposition grounds. A banquet in which the other engineering societies will participate will be held Wednesday evening at the Stevens Hotel.

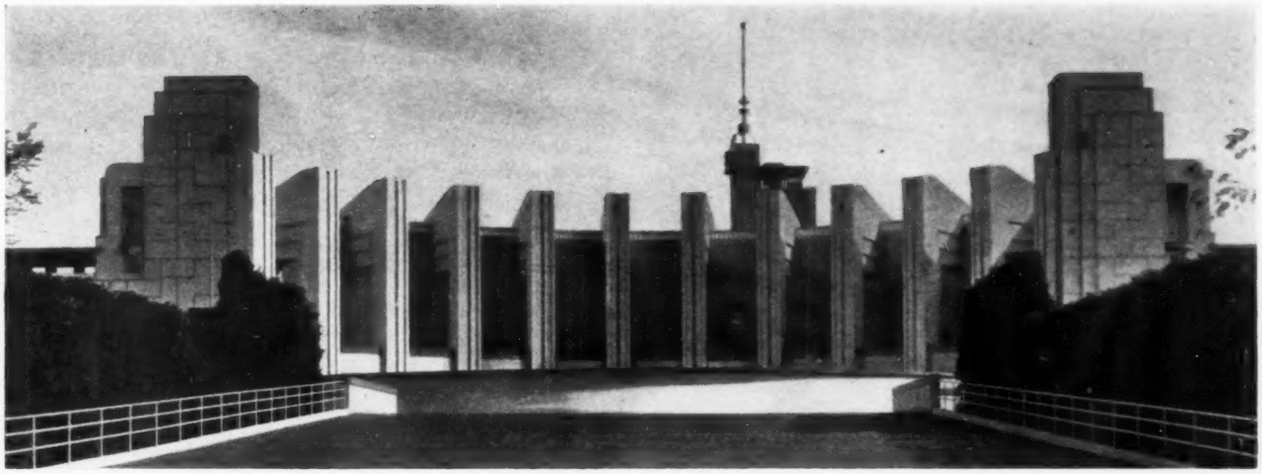
REDUCED RAILROAD RATES

REDUCED fares from many points will be available to A.S.M.E. members and their friends attending the Semi-Annual Meeting of the Society in Chicago. Because of the Century of Progress Exposition, very low rates have been authorized by the railroad passenger associations. *Local ticket agents should be consulted before purchasing tickets.* From Eastern points, a round-trip ticket can be purchased for the price of a one-way fare to Chicago plus thirty cents. These tickets can be used on trains leaving on *Saturday,* June 24, and the return trip must be made within ten days. The Baltimore and Ohio Railroad is planning to run two "Engineers' Specials" on Saturday and Sunday, June 24 and 25. From Pacific coast points, tickets will be sold on the basis of a one-way fare plus fifty cents, with a return limit of 16 days. From various other points a fare and one-tenth has been authorized. Reduced pullman tariffs have been authorized in certain cases.

Where the aforementioned reduced rates do not apply, the certificate plan is effective on the basis of a fare and one-third for the round trip. Certificates should be requested when tickets are purchased and should be validated upon arrival at the Registration Headquarters in the Palmer House, Chicago. Under the certificate plan there is a thirty-day return limit.

ABSTRACTS OF TECHNICAL PAPERS

It has been impossible, in view of the extent of the technical program and the expense of publication in the present financial emergency, for the Society to preprint the papers for the Chicago Meeting. In order to make up for this deficiency and at the same time to provide a basis for discussion, the official program to be distributed at the meeting will contain an abstract of approximately 1000 words of every paper to be presented. When it is considered that in the time allotted to an author for the oral presentation of a paper it is possible to say not more than 1000 words, it will be realized that a surprising amount of the "meat" of the paper can be compressed into this small compass. Copies of abstracts of most of the papers for the A.S.M.E. technical sessions listed in the following program may be obtained by addressing the Secretary, The American Society of Mechanical Engineers, 29 West 39th Street, New York, N. Y.



NORTH ENTRANCE OF THE HALL OF SCIENCE—A CENTURY OF PROGRESS EXPOSITION

A.S.M.E. Program *for* ENGINEERING WEEK

Chicago, Ill., June 25-July 1, 1933

Technical Sessions

(Unless otherwise stated all events will be held at the Palmer House, A.S.M.E. Headquarters for the Meeting)

SUNDAY, JUNE 25

2:00 p.m. Registration opens in the Foyer of the Ballroom of the Palmer House, A.S.M.E. Headquarters for the Meeting

MONDAY MORNING, JUNE 26

9:30 a.m. **Aerodynamics (I)** **Club Room**

Auspices of Aeronautic Division

Presiding Officer: A. Klemin, Secretary, A.S.M.E. Aeronautic Division, and Director Aeronautical Engineering, Guggenheim School of Aeronautics, New York University, New York, N. Y.

Staff Representative: Professor Daniel Roesch

Some Design Problems and Their Solution in the Wind Tunnel, Th. von Kármán, Mem. A.S.M.E., Director, and Clark B. Millikan, Assoc-Mem. A.S.M.E., Assistant Professor of Aeronautics, California Institute of Technology, Pasadena, Calif.

Some Studies on the Flutter of Airfoils and Propellers, W. Harold Taylor, Mem. A.S.M.E., Ann Arbor, Mich.

Airplane Wing Profiles With a Given Initial Moment, C. Witoszynski, Aerodynamics Institute, Warsaw, Poland (Presented by M. J. Thompson)

Aerodynamics, C. Wieselberger, Technische Hochschule, Aachen, Germany (Presented by William H. Miller, Mem. A.S.M.E., Research Chief, B/J Aircraft Corporation, Baltimore, Md.)

9:30 a.m. **Printing (I)** **Ballroom**

Auspices of Printing Industries Division

Presiding Officer: Floyd E. Wilder, Chairman, A.S.M.E. Printing Industries Division; Hearst Publications, New York, N. Y.

Staff Representative: Joseph R. Blaine

Printing Progress, by Special Committee consisting of Burt D. Stevens, *Chairman*, Mem. A.S.M.E., Vice-President, Miehle Printing Press & Mfg. Co., Chicago, Ill.; George H. Carter, Mem. A.S.M.E., The Public Printer of the United States, Government Printing Office, Washington, D. C., and Floyd E. Wilder

Printing Progress and Labor, George L. Berry, President, International Printing Pressmen's and Assistants' Union, Pressmen's Home, Tenn.

9:30 a.m. **Fuels (I)** **Red Lacquer Room**

Auspices of Fuels Division

Presiding Officer: R. A. Sherman, Chairman, A.S.M.E. Fuels Division; Battelle Memorial Institute, Columbus, Ohio

Staff Representative: Harvey Twedt

A Century of Progress in Fuel Technology, O. P. Hood, Mem. A.S.M.E., Chief, Technologic Branch, Bureau of Mines, U. S. Department of Commerce, Washington, D. C.

9:30 a.m. **Machine-Shop Practice (I)** **Room 14**

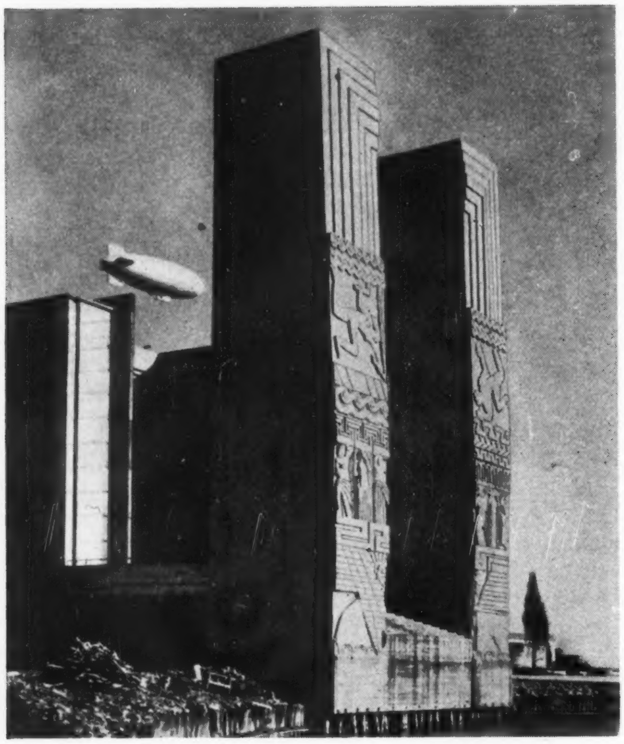
Auspices of Special Research Committee on Cutting of Metals

Presiding Officer: C. J. Oxford, Factory Superintendent and Chief Engineer, National Twist Drill & Tool Co., Detroit, Mich.

Staff Representative: Prof. Jos. S. Kozacka

Elements of Milling, Part 2, O. W. Boston, Mem. A.S.M.E., University of Michigan, and C. E. Kraus, University of Michigan, Ann Arbor, Mich.

Cemented Carbide Cutting Tools, Malcolm F. Judkins, Jun. A.S.M.E., Engineer in Charge, Firthite Division, and William C. Uecker, Engineering Department, Firth-Sterling Steel Co., McKeesport, Pa.



TWIN PYLONS GUARD WATER GATE TO ELECTRIC BUILDING—A CENTURY OF PROGRESS EXPOSITION

9:30 a.m. Plastic Deformation Room 404

Auspices of Iron and Steel Division and Plasticity Committee of Applied Mechanics Division

Presiding Officer: A. NADAI, Mem. A.S.M.E., Research Laboratory, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Staff Representative: G. GAY CARMAN

Practical Plasticity Problems, GEORGE M. EATON, Mem. A.S.M.E., Director of Research, Spang-Chalfant & Co., Inc., Ambridge, Pa.
On the New Theory of Plasticity, Strain Hardening, and Creep, H. HENCKY, Mem. A.S.M.E., Massachusetts Institute of Technology
The Influence of Rate of Shear Upon the Shearing Strength of Lead, JAMES JAMIESON, Ann Arbor, Mich.

9:30 a.m. Railroad Research (I) Room 405

Auspices of Railroad Division

Presiding Officer: L. A. DOWNS, President, Illinois Central Railroad

Staff Representative: E. L. WOODWARD

Introductory Remarks, R. H. AISHTON, Chairman of Board, American Railway Association
Research Accomplished by Railroads, C. D. YOUNG, Vice-President, Pennsylvania Railroad
Research Accomplished by Industry, SAMUEL DUNN, Chairman of Board, Simmons-Boardman Publishing Co., Chicago, Ill.
Research Accomplished by Universities, G. A. YOUNG, Mem. A.S.M.E., Head of School of Mechanical Engineering, Purdue University, Lafayette, Ind., and E. C. SCHMIDT, Department of Railway Engineering, University of Illinois, Urbana, Ill.

9:30 a.m. Boiler Feedwater Room 10

Auspices of Joint Research Committee on Boiler Feedwater Studies

Presiding Officer: S. T. POWELL, Chairman of Committee, Consulting Engineer, Baltimore, Md.

Staff Representative: HAROLD G. FROBERG

The Effect of Suspended Solids. Progress Report of Subcommittee No. 3 on Priming and Foaming, of the Joint Research Committee on Boiler Feedwater Studies, C. W. FOULK, Chairman of Subcommittee
Three additional subcommittee reports

MONDAY AFTERNOON, JUNE 26

2:15 p.m. Aerodynamics (II) Club Room

Auspices of Aeronautic Division

Presiding Officer: E. E. ALDRIN, Mem. A.S.M.E., Standard Oil Company of New Jersey, New York, N. Y.

Staff Representative: PROFESSOR DANIEL ROESCH

Zap Flaps and Ailerons, TEMPLE N. JOYCE, President, B/J Aircraft Corp., Baltimore, Md.
Introduction to the Spin, A. KLEMIN, Secretary, A.S.M.E. Aeronautic Division, and Director Aeronautical Engineering, Guggenheim School of Aeronautics, New York University, New York, N. Y.
Rules for the Construction of Airplanes, A. VOLMERANGE, Bureau Veritas, Paris, France (Presented by A. KLEMIN)

2:15 p.m. Printing (II) Ballroom

Auspices of Printing Industries Division

Presiding Officer: GEORGE C. VAN VECHTEN, Assoc-Mem. A.S.M.E., Superintendent, Stecher Lithograph Co., Rochester, N. Y.

Staff Representative: EDWARD F. DUDLEY

Program of Cooperative Printing Research in America, ARTHUR C. JEWETT, Mem. A.S.M.E., Director, College of Industries, Carnegie Institute of Technology, Pittsburgh, Pa.
An Analysis of Printing Research, DR. HENRY D. HUBBARD, Assistant to the Director of the Bureau of Standards, Washington, D. C.
Press Drive and Control for Modern Presses, JOSEPH E. RIDDER, Vice-President, *Journal of Commerce*, New York, N. Y.
Informal Discussion of Photoelectric Tube Application, Ink Drying by Violet Ray, Stroboscope, Etc.

2:15 p.m. Fuels (II) Red Lacquer Room

Auspices of Fuels Division

Presiding Officer: W. L. ABBOTT, Past-President A.S.M.E., Chief Operating Engineer, Commonwealth Edison Co., Chicago, Ill.

Staff Representative: JOHN WARDELL

Standby and Reserve Operation of a Pulverized-Fuel Plant, E. H. TENNEY, Mem. A.S.M.E., Chief Engineer, Power Plants, Union Electric Light & Power Co., St. Louis, Mo.
Oil Firing in Pulverized-Coal Furnaces, JAMES F. MUIR, Mem. A.S.M.E., Mechanical Engineer, Montaup Electric Co., Somerset, Mass.

2:15 p.m. Machine-Shop Practice (II) Room 14

Auspices of Machine Shop Practice Division

Presiding Officer: R. E. W. HARRISON, Secretary, A.S.M.E. Machine Shop Practice Division, and Consulting Engineer, Cincinnati, Ohio

Staff Representative: PROF. JOS. S. KOZACKA

Recent Progress in X-Ray Inspection of Welds, HERBERT R. ISENBERGER, St. John X-Ray Service Corporation, New York, N. Y.
Results of Research Relating to the Theory of Metal Cutting, FRIEDRICH SCHWERD, Hanover, Germany

2:15 p.m. Iron and Steel Room 404

Auspices of the Iron and Steel Division and Plasticity Committee of the Applied Mechanics Division

Presiding Officer: A. J. BOYNTON, Chairman, A.S.M.E. Iron and Steel Division; H. A. Brassert & Co., Chicago, Ill.

Staff Representative: G. GAY CARMAN

Roll Neck Bearings, Progress Report No. 10 of A.S.M.E. Special Research Committee on Heavy Duty Anti-Friction Bearings, W. TRINKS, Mem. A.S.M.E., Professor of Mechanical Engineering, Carnegie Institute of Technology, Pittsburgh, Pa.; and J. H. HITCHCOCK, Secretary, A.S.M.E. Iron and Steel Division; Morgan Construction Co., Worcester, Mass.
Determination of Inherent Stresses by Measuring Deformation of Drilled Holes, JOSEF MATHAR, Technical University, Aachen, Germany (Presented by TH. VON KÁRMÁN, California Institute of Technology, Pasadena, Calif.)

2:15 p.m. Education and Training Room 10

Auspices of Committee on Education and Training

Presiding Officer: R. L. SACKETT, Manager, A.S.M.E., Dean of Engineering, Pennsylvania State College, State College, Pa.

Staff Representative: PROF. H. P. DUTTON

Education Within Industry in the Central States, ROBERT H. SPAHR, Director, Instruction and Curriculum Development, General Motors Institute of Technology, Flint, Mich.

Training Programs for Apprentices in Times of Depression, JOHN T. FAIG, Mem. A.S.M.E., President of Ohio Mechanics Institute, Cincinnati, Ohio

2:15 p.m. **Railroad Research** **Room 405**

Auspices of Railroad Division

Discussion of Papers in the Morning Session

Research and Development Resulting in the Production of the Standard Freight Cost, F. H. HARDIN, Mem. A.S.M.E., Assistant to President, New York Central Railroad Co., New York, N. Y.

Development of Passenger Cars, PETER PARKS, Pullman Co., Chicago, Ill.

Development of the Locomotive Boiler, HENRY B. OATLEY, Mem. A.S.M.E., Vice-President in Charge of Engineering, Superheater Co., New York, N. Y.

Locomotive Running Gear and Counterbalancing, A. G. TRUMBULL, Mem. A.S.M.E., Chief Mechanical Engineer, Advisory Mechanical Committee, Chesapeake & Ohio, Erie, etc.

Car and Locomotive Air Brakes, SAMUEL W. DUDLEY, Mem. A.S.M.E., Professor of Mechanical Engineering, Yale University, New Haven, Conn.

Automotive Engines and Cars, L. G. COLEMAN, Vice-President, Ingersoll-Rand Co., New York, N. Y.

Car and Locomotive Materials, LAWFORD H. FRY, Mem. A.S.M.E., Railway Engineer, Edgewater Steel Co., Pittsburgh, Pa.

Locomotive Development, W. E. WOODARD, Mem. A.S.M.E., Vice-President, Lima Locomotive Works, Inc., New York, N. Y.

Development of Draft Gear, L. P. MICHAEL, Mem. A.S.M.E., Chief Mechanical Engineer, Chicago & North Western Railway, Chicago, Ill.

Locomotive and Car Wheels, C. T. RIPLEY, Mem. A.S.M.E., Chief Mechanical Engineer, Atchison, Topeka & Santa Fe Railway System, Chicago, Ill.

Locomotive Accessories, C. H. BILTY, Mechanical Engineer, Chicago, Milwaukee, St. Paul & Pacific Railroad Co.

MONDAY EVENING, JUNE 26

8:00 p.m. **Aeronautics** **Club Room**

Auspices of Aeronautic Division

Presiding Officer: CARL B. FRITSCHE, Mem. A.S.M.E., Metalclad Airship Corp., Detroit, Mich.

Staff Representative: MAX WELBORN

Aircraft-Engine Cooling Problems, HAROLD CAMINEZ, Allison Engineering Co., Indianapolis, Ind.

Some Factors Regarding Propellers for Airships, FRED E. WEICK, Senior Aeronautical Engineer, National Advisory Committee for Aeronautics, Langley Memorial Aeronautical Laboratory, Langley Field, Hampton, Va.

Safety Maintenance Manual for Aeronautics (Report of Special Committee on Aircraft Safety and Inspection), JEROME LEDERER, Assoc-Mem. A.S.M.E., Chief Engineer, Barber & Baldwin, New York, N. Y.

TUESDAY MORNING, JUNE 27

9:30 a.m. **Aeronautic Vibration** **Club Room**

Auspices Aeronautic Division

Presiding Officer: E. A. SPERRY, JR., Vice-Chairman, A.S.M.E. Aeronautics Division, and Vice-President, Sperry Products, Inc., Brooklyn, N. Y.

Staff Representative: PROFESSOR DANIEL ROESCH

Noise Elimination in Transport Airplane, P. E. BASSETT and Z. J. ZAND, Sperry Gyroscope Co., Brooklyn, N. Y.

Shock-Absorbing Panels for Instrument Mountings, CHARLES H. DOLAN, Mem. A.S.M.E., Operations Manager, Eastern Air Transport, Inc., Candler Field, Atlanta, Ga.

Air Sickness, L. H. BAUER, M.D., Consulting Specialist in Aviation Medicine, Hempstead, N. Y.

9:30 a.m. **Printing (III)** **Ballroom**

Auspices of Printing Industries Division

Presiding Officer: JOSEPH M. FARRELL, Mem. A.S.M.E., The Blackman Co., New York, N. Y.

Staff Representative: JOSEPH R. BLAINE

Improved Printing Results From Air Conditioning, report prepared by The Cuneo Press, Chicago, Ill.

Use and Care of Rubber Rollers, HARRY B. ADSIT, Mechanical Superintendent, *Pittsburgh Post-Gazette*, Pittsburgh, Pa.

Informal discussion of Developments in Direct-Pressure Stereotyping

9:30 a.m. **Fuels (III)** **Room 404**

Auspices of Fuels Division

Presiding Officer: G. F. GEBHART, Mem. A.S.M.E., Armour Institute of Technology, Chicago, Ill.

Staff Representative: HARVEY TWEDT

Correlation of Grindability With Actual Pulverizer Performance, MARTIN FRISCH, Assoc-Mem. A.S.M.E., Foster Wheeler Corporation, New York, N. Y., and G. C. HOLDER, Chief Chemist, Foster-Wheeler Corporation, New York, N. Y.

The Principles of Underfeed Combustion and the Effect of Preheated Air on Over- and Underfeed Fuel Beds, P. NICHOLLS, Mem. A.S.M.E., Supervising Engineer, Fuels Section, U. S. Bureau of Mines, Pittsburgh Experiment Station, Pittsburgh, Pa., and M. G. EILERS, Associate Fuel Engineer, U. S. Bureau of Mines, Pittsburgh Experiment Station, Pittsburgh, Pa.

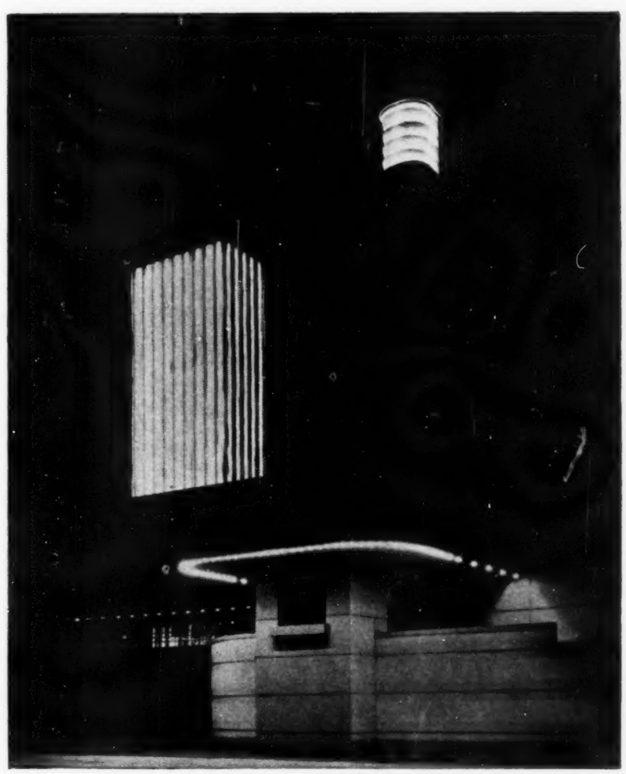
9:30 a.m. **Machine-Shop Foundry** **Room 14**

Auspices of Machine Shop Practice Division and American Foundrymen's Association

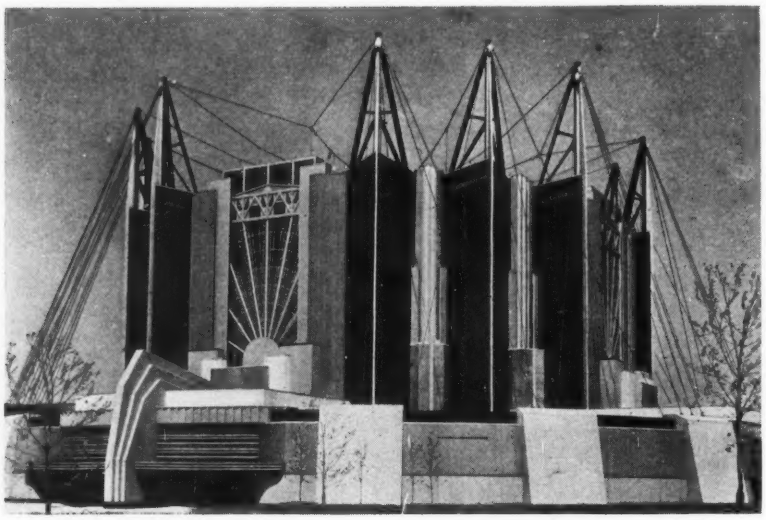
Presiding Officer: W. F. COLEMAN, Assoc-Mem. A.S.M.E., Vice-President, W. A. Jones Foundry & Machine Company, Chicago, Ill.

Staff Representative: PROF. JOS. S. KOZACKA

Development of Cast Iron for Machine Construction, OLIVER SMALLEY, Technical Director, Gray Iron Institute, Inc., Pittsburgh, and W.



CONCEALED LIGHTING MAKES SOUTH VIEW OF HALL OF SCIENCE A SPECTACULAR ONE AT NIGHT



TRAVEL AND TRANSPORT BUILDING WITH ITS "SKY-HUNG" DOME

WORLEY KERLIN, Metallurgist, Gray Iron Institute, Inc., Cleveland, Ohio

Notes on Electric Cast-Iron Practice, H. H. WALTHER, Metallurgist, Dayton Steel Foundry Co., Dayton, Ohio

9:30 a.m. Mechanical Springs Room 405

Auspices of Special Research Committee on Mechanical Springs

Presiding Officer: A. H. PEYCKE, American Steel Foundries, Chicago, Ill.

Staff Representative: PROF. J. C. PEEBLES

Stresses in Helical Springs, ROBERT F. VOGT, Mem. A.S.M.E., Assistant Chief Consulting Engineer, Allis-Chalmers Mfg. Co., West Allis, Wis.

Influence of Corrosion Pits and Other Notches on Fatigue of Metals, D. J. MCADAM, JR., Metallurgist, U. S. Bureau of Standards, Washington, D. C., and R. W. CLYNE, Mechanical Engineer, American Steel Foundries, Chicago, Ill.

Fatigue Tests of Helical Springs and Notes on Sundry Results of the Test, Progress Report No. 2 of the Subcommittee on Heavy Helical Springs, C. T. EDGERTON, Chairman of Subcommittee, Manager, Bureau of Statistics, Crucible Steel Co. of America, New York.

TUESDAY AFTERNOON, JUNE 27

2:30 p.m. Aeronautic Construction Symposium Club Room

Auspices of Aeronautic Division

Presiding Officer: WILLIAM B. MAYO, Chairman, A.S.M.E. Aeronautic Division, Detroit, Mich.

Staff Representative: MAX WELBORN

Fundamental Principles of Design of Fittings for Metal Monocoque, J. E. YOUNGER, Professor of Mechanical Engineering, University of California, Berkeley, Calif.

The Resistance Welding of Aluminum and Its Alloys, D. I. BOHN, Aluminum Company of America, and G. O. HOGLUND, Jun. A.S.M.E., Aeronautical Engineer, Aluminum Company of America, New Kensington, Pa.

Stainless Steel in Aircraft Construction, FREDERIC FLADER, Aeronautical Engineer, Curtiss Aeroplane and Motor Co., Buffalo, N. Y.

Aircraft Design as Influenced by Accidents, RICHARD C. GAZLEY, Chief, Engineering Section, Aeronautics Branch, Department of Commerce, Washington, D. C.

2:30 p.m. Applied Mechanics Room 404

Auspices of Applied Mechanics Division

Presiding Officer: ROBERT M. GATES, Vice-President, A.S.M.E., Vice-President, Superheater Co., New York, N. Y.

Staff Representative: PROF. J. C. PEEBLES

Influence of Lashing and Centrifugal Force on Turbine-Blade Stresses, R. P. KROON, Jun. A.S.M.E., Engineer, Westinghouse Elec. & Mfg. Co., Lester, Pa.

Effect of Openings in Pressure Vessels, J. HALL TAYLOR, Mem. A.S.M.E., President, Taylor Forge & Pipe Works, Chicago, Ill., and E. O. WATERS, Assoc-Mem. A.S.M.E., Professor of Mechanical Engineering, Yale University, New Haven, Conn.

2:30 p.m. Pulverizing and Dust Room 14

Auspices of Process Industries Committee

Presiding Officer: W. KEITH MCAFEE, Mem. A.S.M.E., New Castle, Pa

Staff Representative: J. W. ANDERSON

Relation Between Pulverizer Capacity, Power, and Grindability, R. M. HARDGROVE, Mem. A.S.M.E., Engineer, Babcock & Wilcox, Co., New York, N. Y.

Characteristics and Mitigation of Industrial Dusts, J. M. DALLAVALLE, Assistant Sanitary Engineer, Public Health Service, Washington, D. C.

2:30 p.m. Smoke Abatement Ballroom

Auspices of Fuels Division

Presiding Officer: ELY C. HUTCHINSON, Mem. A.S.M.E., President, Edge Moor Iron Co., Edge Moor, Del.

Staff Representative: ALBERT BAKER

The Measurement of Properties of Cinders and Fly Ash, ARTHUR C. STERN, Jun. A.S.M.E., Research Instructor in Smoke Abatement, Stevens Institute of Technology, Hoboken, N. J.

Progress in Removal of Sulphur Compounds From Waste Gases, H. J. JOHNSTONE, Department of Chemistry, University of Illinois, Urbana, Ill.

The Human Side of Smoke Abatement, WILLIAM G. CHRISTY, Secretary, A.S.M.E. Fuels Division, and Smoke Abatement Engineer, Department of Smoke Regulation, Hudson County, Jersey City, N. J.

2:30 p.m. Printing Industries Conference Room 405

Auspices of Printing Industries Division

Presiding Officer: WILLIAM C. GLASS, Mem. A.S.M.E., U.P.M.-Kidder Press Co., New York, N. Y.

Staff Representative: EDWARD F. DUDLEY

Topics: Color Photography From Color Negatives
Standardization of Process Colors

TUESDAY EVENING, JUNE 27

8:00 p.m. Science and Engineering Ballroom

Auspices of Engineering Section (M) of A.A.A.S., the A.S.M.E., and other engineering societies

Industrial Developments of the Century, A. P. M. FLEMING, Mem. A.S.M.E., Manager of Research and Education Department, Metropolitan-Vickers Electrical Co., Manchester, England

WEDNESDAY, JUNE 28

10:00 a.m. Engineers' Day Soldier Field

Members, ladies, and guests of the fifteen participating Societies will assemble at 10:00 a.m. in the Stadium at Soldier Field foi the presentation of the Daniel Guggenheim Medal to Mr. Juan de la Cierva, the inventor of the autogiro.

It is expected that Mr. Cierva will arrive at the Stadium in a Pitcairn autogiro.

The Western Society of Engineers, which is acting as a general host to visiting engineers during Engineering Week, will make use of this occasion to welcome the engineers to Chicago.

Afternoon

Following the ceremonies at the Stadium, the group will have luncheon on the Exposition Grounds, after which the afternoon will be spent in an inspection of the attractions and engineering works at the Fair.

Evening

7:00 Joint Engineering Dinner at Stevens Hotel.

Tickets for the Dinner and Evening's Entertainment are $3.00 each.

THURSDAY MORNING, JUNE 29

9:30 a.m. Industrial Power Ballroom

Auspices of Power Division

Presiding Officer: WILL J. SANDO, Mem. A.S.M.E., Advisory Engineer, Reconstruction Finance Corporation, Chicago District, Chicago, Ill.

Staff Representative: JOHN WARDELL

Application of High-Boiling-Point Organic Compounds to Industrial Heat-Exchange Problems, J. J. GREBE, Assoc-Mem. A.S.M.E., Director, Physical Research, Dow Chemical Co., and E. F. HOLSER, Engineering Department, Dow Chemical Co., Midland, Mich.

A Graphical Method for the Design of Flexible Members for Steel Piping, E. A. WERT, Mem. A.S.M.E., Piping Division, Detroit Edison Co., S. SMITH, Piping Division, Detroit Edison Co., and E. T. COPE, Mem. A.S.M.E., Research Department, Detroit Edison Co., Detroit, Mich.

Hydraulic and Water Power (I)
9:30 a.m. Room 14

Auspices of A.S.M.E. Hydraulic and A.S.C.E. Power Divisions

Flow of Water Around Bends in Open and Closed Channels, DAVID L. YARNELL, Senior Drainage Engineer, U. S. Department of Agriculture, Iowa City, Iowa; and FLOYD A. NAGLER, Professor of Hydraulic Engineering, University of Iowa, Iowa City, Iowa (A.S.C.E. paper)

Report of Power Division Committee, A.S.C.E., on Legislation Respecting Safety of Dams, R. A. MONROE, Vice-Chairman of Committee; Civil and Hydraulic Engineer, Aluminum Company of America, Pittsburgh, Pa.

9:30 a.m. Applied Mechanics and Structures (I) Room 404

Auspices of A.S.M.E. Applied Mechanics and A.S.C.E. Structural Divisions

Presiding Officer: F. E. TURNEAURE, University of Wisconsin, Madison, Wis.

Staff Representative: PROF. J. C. PEEBLES

Rational Design of Steel Columns, D. H. YOUNG, Instructor, University of Michigan, Ann Arbor, Mich.

Stability of the Web of Plate Girders, S. TIMOSHENKO, Mem. A.S.M.E., Professor of Mechanical Engineering, University of Michigan, Ann Arbor, Mich.

Stability of Thin-Walled Tubes Under Torsion, L. H. DONNELL, Mem. A.S.M.E., Research Engineer, Aeronautics Department, California Institute of Technology, Pasadena, Calif.

9:30 a.m. Management Room 405

Auspices of Management Division

Presiding Officer: C. B. AUEL, Chairman, A.S.M.E. Committee on Elimination of Waste, and Manager, Employment Service Department, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Staff Representative: PROF. H. P. DUTTON

Factors to Be Considered in the Substitution of a Different Material in a Product, J. L. ALDEN, Mem. A.S.M.E., Assistant Superintendent, Manufacturing Development, Western Electric Co., Chicago, Ill.

Principles of Coordinated Visual Control, EUGENE SZEPESI, Mem. A.S.M.E., Consulting Management Engineer, New York, N. Y.

THURSDAY AFTERNOON, JUNE 29

2:15 p.m. Management Room 405

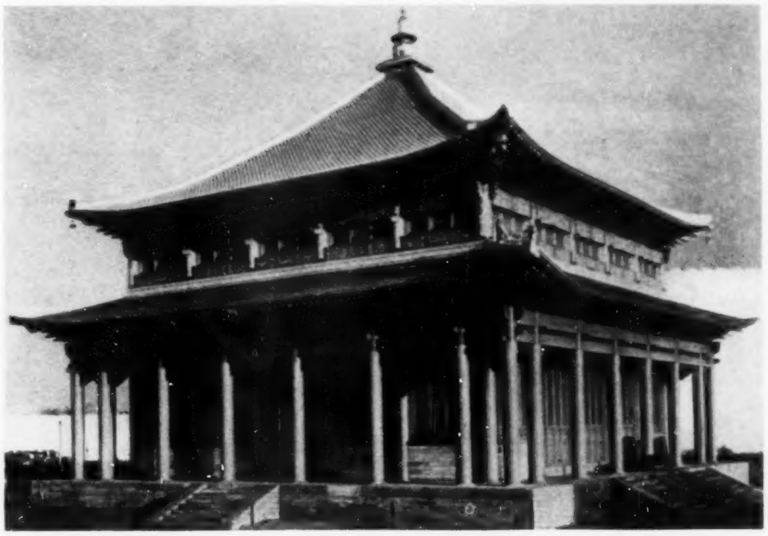
Auspices of Management Division

Presiding Officer: L. P. ALFORD, Mem. A.S.M.E., Vice-President, Ronald Press Co., N. Y.

Staff Representative: PROF. H. P. DUTTON

Present Tendencies in Organizing for Manufacture of Diversified Product, A. F. MURRAY, Mem. A.S.M.E., Director of Manufacturing Operations, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

The Economic Significance of Replacement Cycle in Demand, T. M. MCNIECE, Industrial and Marketing Analyst, New York, N. Y.



REPLICA OF GOLDEN TEMPLE OF JEHOL, CELEBRATED LAMA TEMPLE

2:15 p.m. Process Room 10

Auspices of Process Industries Committee

Presiding Officer: CARLOS E. HARRINGTON, Chairman, A.S.M.E. Process Industries Committee; University of Buffalo, Buffalo, N. Y.

Staff Representative: B. SCHROEDER

Mechanical Development in Municipal Sanitation, W. RAISCH, Jun. A.S.M.E., General Manager and Chief Engineer, Municipal Sanitary Service Co., New York, N. Y.

Factors and Problems in Conditioning, Cooking, and Pressing Cottonseed Meats, W. R. WOOLRICH, Mem. A.S.M.E., Professor of Mechanical Engineering, University of Tennessee, and E. L. CARPENTER, Mem. A.S.M.E., Assistant Professor in Charge of Engineering Extension, University of Tennessee, Knoxville, Tenn.

The De-Airing of Clays in the Ceramic Industry, H. R. STRAIGHT, Mem. A.S.M.E., President, Adel Clay Products Co., Adel, Iowa

2:15 p.m. Hydraulic and Water Power (II) Ballroom

Auspices of A.S.M.E. Hydraulic and A.S.C.E. Power Divisions

Résumé of the Engineering Reports on the St. Lawrence Power Development, DANIEL W. MEAD, Mem. A.S.M.E., Hydraulic and Sanitary Engineer, University of Wisconsin; and THOMAS H. HOGG, Chief Hydraulic Engineer, Hydroelectric Power Commission of Ontario, Toronto, Ontario, Canada

Discussion of St. Lawrence Waterway

2:15 p.m. Applied Mechanics and Structures (II) Room 404

Auspices of A.S.M.E. Applied Mechanics and A.S.C.E. Structural Divisions

Presiding Officer: C. T. MORRIS, Structural Engineer, Ohio State University, Columbus, Ohio

Laboratory Tests of Multiple-Span Reinforced-Concrete Arches, W. M. WILSON, Research Professor, Structural Engineer, University of Illinois, Urbana, Ill. (A.S.C.E. paper)

Wind Pressure on Buildings, O. FLACHSBART, Lehrstule für Mechanik, Technische Hochschule, Hanover, Germany (A.S.C.E. paper)

Tests of Split-H End Connections for Wind Girders, W. C. HUNTINGTON, Head of Department of Civil Engineering, University of Illinois, Urbana, Ill. (A.S.C.E. paper)

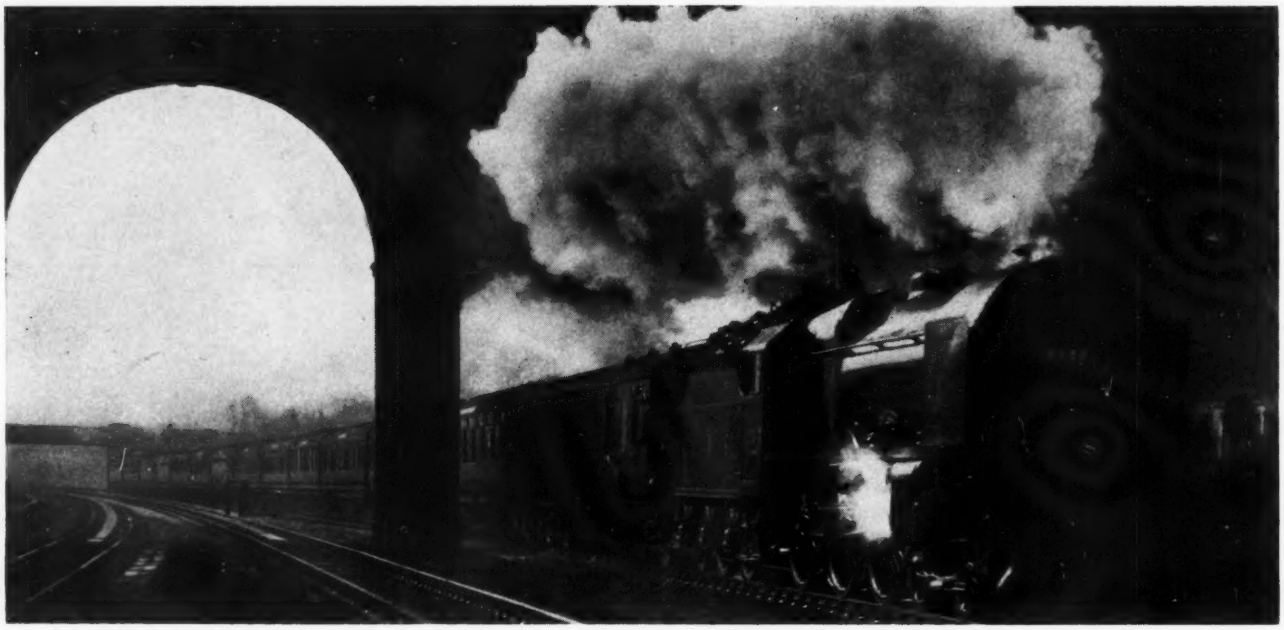
FRIDAY MORNING, JUNE 30

9:30 a.m. Central-Station Power (I) Ballroom

Auspices of Power Division

Presiding Officer: JOHN M. DRABELLE, Mem. A.S.M.E., Mechanical and Electrical Engineer, Iowa Railway & Light Corp., C. R. & I. C. Railway Co., Cedar Rapids, Iowa

Staff Representative: HAROLD G. FROBERG



"THE ROYAL SCOT," FAMOUS EXPRESS OF LONDON, MIDLAND & SCOTTISH RAILWAY, TO BE ON EXHIBITION AT A CENTURY OF PROGRESS EXPOSITION

Performance of Two 101,000-Sq Ft Surface Condensers, J. N. LANDIS, Assoc-Mem. A.S.M.E., Assistant Mechanical Engineer, Brooklyn Edison Co., Brooklyn, N. Y.

Surface-Condenser Design and Operating Characteristics, TOWNSEND TINKER, Jun. A.S.M.E., Ross Heater and Manufacturing Co., Buffalo, N. Y.

A Thermal Study of Available Steam-Power-Plant Heat Cycles, G. A. HENDRICKSON, Assoc-Mem. A.S.M.E., Engineer, Detroit Edison Co., Detroit, Mich., and S. T. VESSELOWSKY, Engineer, Detroit Edison Co., Detroit, Mich.

9:30 a.m. Hydraulic and Water Power (III) Room 14

Auspices of A.S.M.E. Hydraulic and A.S.C.E. Power Divisions

Presiding Officer: L. F. HARZA, Mem. A.S.M.E., President, Harza Engineering Co., Chicago, Ill.

Staff Representative: F. E. PEACOCK

WATER-HAMMER SYMPOSIUM:

Comparison of Water-Hammer Theory, With Recommended Symbols and Bibliography by Committee on Water Hammer, S. LOGAN KERR, *Chairman*, N. R. GIBSON, EUGENE E. HALMOS, LEWIS F. MOODY, RAY S. QUICK, and EARL B. STROWGER

Simplified Derivation of Water-Hammer Formula, L. F. MOODY, Mem. A.S.M.E., Professor of Hydraulic Engineering, Princeton University, Princeton, N. J.

High-Head Penstock Design, A. W. K. BILLINGS, Mem. A.S.M.E., Vice-President, Brazilian Traction, Light, and Power Co., Ltd., Rio de Janeiro, Brazil, S. A., and O. H. DODKIN, Hydraulic Engineer, F. KNAPP, Assistant Hydraulic Engineer, ADOLPHO SANTOS, JR., Assistant Hydraulic Engineer, all of Sao Paulo Tramway, Light, and Power Co., Sao Paulo, Brazil

Influence of Water Hammer on Design of High-Head Penstocks at the Drum Plant and Tiger Creek Plant, WALTER DREYER, Assistant Chief, Division of Civil Engineering, Pacific Gas & Electric Co., San Francisco, Calif.

Computation of Water-Hammer Pressures in Compound Pipes, ROBERT E. GLOVER, Engineer, U. S. Bureau of Reclamation, Denver, Colo.

Effect of Surge Tanks and Surge-Tank Risers on Water-Hammer Computations, EUGENE E. HALMOS, Chief Engineer, Parklap Construction Corp., New York, N. Y.

Surge Control in Centrifugal-Pump Discharge Lines, RAY S. QUICK, Assoc-Mem. A.S.M.E., Chief Engineer, Pelton Wheel Co., San Francisco, Calif.

Water-Hammer Tests in Croton Lake Pumping Plant, S. LOGAN KERR, Assoc-Mem. A.S.M.E., Water Works Engineer, Baldwin Southwark Corp., Philadelphia, Pa.

(*Symposium will be continued at Afternoon Session*)

9:30 a.m. Applied Mechanics, Structures (III) Room 404

Auspices of A.S.M.E. Applied Mechanics and A.S.C.E. Structural Divisions

Presiding Officer: J. M. LESSELLS, Chairman, A.S.M.E. Applied Mechanics Division, Mem. A.S.M.E., Westinghouse Elec. & Mfg. Co., South Philadelphia, Pa.

Staff Representative: J. W. ANDERSON

Impact Effect on Bridges, R. BERNHARD, German Railway System, Berlin, Germany

Graphostatics of Stress Functions, H. M. WESTERGAARD, Professor of Theoretical and Applied Mechanics, University of Illinois, Urbana, Ill.

The Amplitudes of Non-Harmonic Vibrations, J. P. DEN HARTOG, Assoc-Mem. A.S.M.E., Assistant Professor of Applied Mechanics, Harvard University, Cambridge, Mass.

Demonstrations

9:30 a.m. Wood Industries (I) Room 10

Auspices of Wood Industries Division

Presiding Officer: THOMAS D. PERRY, Mem. A.S.M.E., Works Manager, Engineer, New Albany Veneer Co., New Albany, Ind.

Staff Representative: ALBERT BAKER

Dry-Film Gluing in Plywood Manufacture, RAY SORENSEN, Secretary, Tego Glufilm, Inc., Louisville, Kentucky

Utility of Variable Displacement Pumps for Hot Pressing in Plywood Operations, ELEK K. BENEDEK, Consulting Engineer, Hydraulic Press Manufacturing Co., Mt. Gilead, Ohio

Plywood as a Building Material, PHILIP S. HILL, Chicago District Manager, Harbor Plywood Corporation, Chicago, Ill.

FRIDAY AFTERNOON, JUNE 30

2:15 p.m. Central-Station Power (II) Ballroom

Auspices of Power Division

Presiding Officer: ALEX D. BAILEY, Manager, A.S.M.E., Superintendent of Generating Stations, Commonwealth Edison Co., Chicago, Ill.

Staff Representative: J. W. ANDERSON

Characteristics of Large Hell Gate Direct-Fired Boiler Units, W. E. CALDWELL, Mem. A.S.M.E., Research Engineer, United Electric Light & Power Co., New York, N. Y.

The Study of Calcium-Sulphate Scale Prevention at Higher Steam Pres-

sures, F. G. STRAUB, Professor of Special Research, University of Illinois, Urbana, Ill.

Moisture Problem in Steam Turbines, C. RICHARD SODERBERG, Mem. A.S.M.E., Manager, Turbine-Apparatus Division, Westinghouse Elec. & Mfg. Co., South Philadelphia, Pa.

2:15 p.m. Hydraulic and Water Power (IV) Room 14

Auspices of A.S.M.E. Hydraulic Division and A.S.C.E. Power Division

Staff Representative: H. P. MCKEAN

Continuation of discussion of Water-Hammer Symposium, to be led by N. R. Gibson

2:15 p.m. Applied Mechanics, Structures (IV) Room 404

Auspices of A.S.M.E. Applied Mechanics and A.S.C.E. Structural Divisions

Presiding Officer: O. H. AMMANN, Chief Engineer, Port of New York Authority, New York

A Generalized Deflection Theory for Suspension Bridges Including the Analysis of Continuous Spans, D. B. STEINMAN, Mem. A.S.C.E., Consulting Engineer, Robinson and Steinman, New York, N. Y. (A.S.C.E. paper)

A Suspension Stiffening Truss of Tension Members as Developed for the Chicago Skyway, WILLIAM G. GROVE, Mem. A.S.C.E., Mem. A.S.M.E., Robinson and Steinman, New York, N. Y. (A.S.C.E. paper)

The Theory of the Suspension Bridge, A. A. JAKKULA, Jun. Mem. A.S.C.E., Instructor, Department of Civil Engineering, University of Michigan, Ann Arbor, Mich. (A.S.C.E. paper)

2:15 p.m. Wood Industries (II) Room 10

Auspices of Wood Industries Division

Presiding Officer: CHESTER L. BABCOCK, Assoc-Mem. A.S.M.E., President, Babcock Machinery Corporation, New York, N. Y.

Staff Representative: B. SCHROEDER

The Compressed-Air Plant for Woodworking Shops, P. S. MURPHY, Industrial Engineer, Ingersoll-Rand Co., Chicago, Ill.

The Application and Performance of Compressed Air in Woodworking Machinery, R. F. ONSRUD, Secretary, Onsrud Machine Works, Inc., Chicago, Ill.

Compressed-Air Equipment for Finishing Woodwork, J. A. PAASCHE, President, Paasche Air Brush Co., Chicago, Ill.

2:15 p.m. Economics Room 405

Auspices of Econometric Society, jointly with A.S.M.E., A.S.C.E., A.I.E.E., A.S.T.M.

Presiding Officer: IRVING FISHER, Yale University, President of the Econometric Society

Contributions of the Mathematician to Economics, CHARLES F. ROOS, Secretary of the Econometric Society. Discussion led by G. C. EVANS, Rice Institute

Rational Basis for Interpreting Economic and Engineering Data, THORNTON C. FRY, Bell Telephone Laboratories, New York, N. Y. Discussion led by HAROLD HOTELLING, Columbia University, New York, N. Y., and L. K. SILLCOX, Mem. A.S.M.E., Vice-President, New York Air Brake Co., Watertown, N. Y.

The Engineering Economist of the Future, DEXTER S. KIMBALL, Past-President, A.S.M.E., Dean, College of Engineering, Cornell University, Ithaca, N. Y. Discussion led by C. F. HIRSHFELD, Mem. A.S.M.E., Director of Research, Detroit Edison Co., Detroit, Mich., and F. E. RAYMOND, Assoc-Mem. A.S.M.E., Massachusetts Institute of Technology, Cambridge, Mass.

FRIDAY EVENING, JUNE 30

8:00 p.m. Economics Red Lacquer Room

Auspices of Econometric Society, jointly with A.S.M.E., A.S.C.E., A.I.E.E., and A.S.T.M.

Presiding Officer: RALPH E. FLANDERS, Mem. A.S.M.E., Chairman of the Committee on Economic Balance, American Engineering Council

Some Fundamental Problems of the Engineer, DR. F. B. JEWETT, Vice-President, American Telephone & Telegraph Co., New York, N. Y.

The Internationalization of Scientific Knowledge as a Factor in World Economic Recovery, A. P. M. FLEMING, Mem. A.S.M.E., Manager of Research and Education Department, Metropolitan-Vickers Electrical Co., Manchester, England

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[The A.S.M.E. Materials Handling Division will cooperate in a session of the American Foundrymen's Convention, at the Stevens Hotel, on Friday morning, June 23, at 10:00 a.m., when the following papers will be presented:

The Field of Materials Handling in Small Foundries, MAX AMOS, Standard Automotive Parts Co., Muskegon, Mich.

The Field of Materials Handling in Semi-Production Foundries, W. L. SEELBACH, Forest City Foundries Co., Cleveland, Ohio]

Non-Technical Events

SUNDAY, JUNE 25

12:30 p.m. Council, Luncheon Meeting, Room 9

5:30 p.m. Dinner of Council and Standing and Special Committees, Room 10

MONDAY, JUNE 26

12:15 p.m. Luncheon, Ballroom

Presiding Officer: A. A. POTTER, President, A.S.M.E.

Speaker: HON. F. J. KELLY, Engineer, Mayor of Chicago

2:00 p.m. Plant Visit: Chicago Freight Tunnels

6:30 p.m. Council Meeting, Room 10

8:00 p.m. Open House and Reception, Ballroom
Musical Program
Dancing

TUESDAY, JUNE 27

8:00 a.m. Local Sections' Conference, at Breakfast, Room 10

12:15 p.m. Luncheon, Ballroom

Presiding Officer: J. D. CUNNINGHAM, Vice-President, A.S.M.E.

Speaker: DR. ALLEN D. ALBERT, A Century of Progress Exposition

2:00 p.m. Business Meeting, Ballroom (Technical Sessions to convene upon adjournment of Business Session)

2:00 p.m. Plant Visit: State Line Generating Station

6:00 p.m. Joint Dinner of Boards of Founder Societies, Room 10

8:00 p.m. Joint Meeting of engineering societies with Section M of the American Association for the Advancement of Science, Ballroom

Speaker: DR. A. P. M. FLEMING, Industrial Developments of the Century

WEDNESDAY, JUNE 28

10:00 a.m. Assembly of all engineering societies represented in Engineering Week at Soldier Field Stadium
Military demonstrations
Musical program by military bands and drum and bugle corps
Brief remarks by visiting dignitaries and eminent foreign engineers
Aerial parade escorting Guggenheim Medalist in autogiro
Landing of autogiro in Soldier Field
Presentation of Guggenheim Award to Juan de la Cierva, inventor of the autogiro

12:00 p.m. Luncheon at individual convenience

1:30 p.m. Assembly at Travel and Transport Building
Series of tours to interesting exhibits and demonstrations, including: Car Assembly Line, General Motors Building; Motor Assembly, Chrysler Building; Tire Manufacturing Plant, Firestone Tire and Rubber Co.; Scientific Exhibits at Hall of Science

7:00 p.m. Joint Banquet of all engineering societies participating in meeting: Stevens Hotel
Eminent foreign engineers, scientists, and officials of participating societies will be introduced
Dancing

THURSDAY, JUNE 29

12:15 p.m. Luncheon, Ballroom. Price $1.25

(Jointly with Society of American Military Engineers and the American Society of Civil Engineers)

Presiding Officer: Col. Elbert A. Gibbs, President, S.A.M.E.

Speaker: Maj-Gen. Lytle Brown, Chief of Engineers, United States Army

1:30 p.m. Plant Visit: Inland Steel Company
(Joint tour by A.S.M.E. and A.I.M.E., made by New York Central Train from LaSalle Street Station)

7:30 p.m. Boat ride, with A.S.M.E., A.S.C.E., and A.S.T.M. participating. Boat will leave pier at Chicago River and Michigan Avenue Bridge. Ample opportunity will be offered to view Chicago's beautifully lighted skyline, the Century of Progress Exposition Grounds, and to witness the fireworks and spectacular lighting display. Return to pier about 11:30. Music for dancing will be provided; a box supper may be obtained at a slight additional charge.
Tickets for this event may be purchased at the Registration Headquarters of the participating societies. *Members are requested to register for this trip prior to their arrival at Chicago* to aid local committee arrangements. Price $1.00, without supper

FRIDAY, JUNE 30

12:15 p.m. Luncheon, Ballroom

Presiding Officer: Alex D. Bailey, Manager, A.S.M.E.

Speaker: Juan de la Cierva, Guggenheim Medalist

2:00 p.m. Plant Visits: Victor Manufacturing Gasket Co., and Kropp Forge Co.

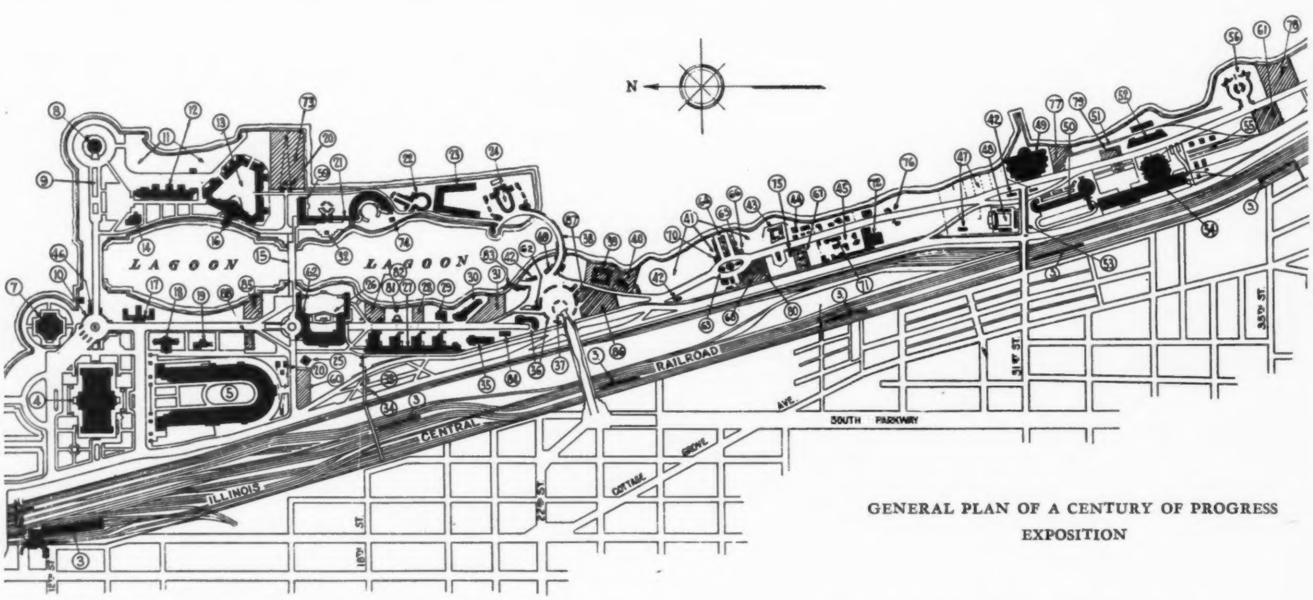
Additional Plant Trips:

In addition to the plants mentioned in the program, the plants and points of interest listed below may be visited any afternoon during the period of the meeting. Transportation arrangements will be made by the individual, but it is suggested that all visitors appear at the plants or other points of interest not later than 3:00 p.m. Available for inspection are:

New Chicago Post Office, World's Largest
Chicago Municipal Airport
Mars, Inc., Candy Manufacturers
National Broadcasting Company Studios
Swift & Co., Packing Plant
Armour & Co., Packing Plant
Wilson & Co., Packing Plant
General Electric Appliance Co., Manufacturers of Household Appliances
Field Museum
Shedd Aquarium
Museum of Science and Industry
Art Institute
Chicago Daily News Printing Plant
Chicago Daily Tribune Printing Plant

Golf: While there will be no provision for golf tournaments during the period of the meeting, members wishing to arrange for small parties may do so at the Registration Desk at Headquarters. Members of the Chicago Section of the A.S.M.E. who are also members of golf clubs in the Chicago district are prepared to entertain a limited number of members. Excellent daily-fee courses will be available at all times throughout the meeting. Many of these courses are easily reached by surface and rapid-transit lines.

Women's Program: An excellent program for the women is being prepared. Among the events will be bridge, visits to the Art Institute and Field Museum, a tour of the boulevards and park system of Chicago, and shopping tours through some of Chicago's great department stores. The principal visit to the Exposition Grounds will be that on Wednesday when the women will participate in the Soldier Field program and then make a tour of the most interesting exhibits. Daily musical programs on the grounds will be of interest.



GENERAL PLAN OF A CENTURY OF PROGRESS EXPOSITION

(3) Illinois Central Stations
(4) Field Museum
(5) Soldier Field
(7) Shedd Aquarium
(8) Adler Planetarium
(9) Terrazzo Promenade
(10) 12th Street Entrance
(11) Beach
(12) Agricultural Group
(13) States Group
(14) Century Dairy Exhibit, Inc.
(15) 16th Street Bridge
(16) U. S. Government Building
(17) Administration Building
(18) Sears, Roebuck Building
(19) Illinois Host House
(20) Skyway & Observation Tower
(21) Electrical Group
(22) Enchanted Island for Children
(23) Horticultural Exhibit, Inc.
(24) Hollywood
(25) Bendix Lama Temple
(26) Hall of Science
(27) General Exhibits Group
(28) Christian Science Pub. Soc.
(29) Blue Ribbon Restaurant
(30) Religion
(31) China
(32) Edison Memorial
(33) Bus Terminal
(34) 18th Street Entrance
(35) American Radiator
(36) Firestone
(37) 23rd Street Entrance
(38) 23rd Street Lagoon Bridge
(39) India
(40) Old Heidelberg Inn
(41) Midway
(42) Crown Food Co.
(43) Fort Dearborn
(44) Lincoln Group
(45) Home and Industrial Arts
(46) Restaurant—Eitel, Inc.
(47) Anthropology Group
(48) Mayan Temple
(49) General Motors Building
(50) Chrysler Building
(51) Tracks for Pageant of Transportation
(52) Grand Stand and Stage for Pageant of Transportation
(53) 31st Street Entrance
(54) Travel and Transport Building
(55) T. & T. Tracks and Exhibit Space
(56) Goodyear Zeppelin
(59) Social Science
(60) Japan
(61) National Poultry Council
(62) Walgreen Co.
(63) Maynes-Illions Rides
(64) Flying Turns
(65) African Dips
(66) Shooting Gallery
(67) Seminole Indian Village
(68) Captive Balloon
(69) Doughnut Machine Corp.
(70) Edwards Rancho
(71) Victor Vienna Cafe
(72) Home Planning Hall
(73) Picnic Grounds
(74) Concession Kiosk
(75) Fort Dearborn Massacre Bldg.
(76) Concession Group
(77) Pal-Waukee Airport
(78) All-Africa Group
(79) Air Show, Inc.
(80) Laff-in-the-Dark
(81) Concession Pergola
(82) Time and Fortune Magazine Pavilion
(83) "City of New York"
(84) Sinclair Refining Co.
(85) Italy
(86) Belgium
(87) Morocco
(88) Sweden